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Effects of Perceived Linguistic Competence and Textbook Linguistic Complexity on Science Achievement through Engagement Profiles Among Seventh-Grade Students

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EFFECTS OF PERCEIVED LINGUISTIC COMPETENCE AND TEXTBOOK LINGUISTIC COMPLEXITY ON SCIENCE ACHIEVEMENT THROUGH ENGAGEMENT PROFILES AMONG SEVENTH-GRADE STUDENTS

BY

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Henos Ejigu Wondimagegn

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Educational Psychology

Principal Advisor: Professor Dawit Asrat Getahun

Co-advisor: Dr. Tiruwork Tamiru Tolla (Associate Professor)

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Bahir Dar, Ethiopia

DECLARATION

This is to certify that the thesis entitled "**Effects of Perceived Linguistic Competence and Textbook Linguistic Complexity on Science Achievement through Engagement Profiles Among Seventh-Grade Students**," submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Educational Psychology in the Department of Psychology at Bahir Dar University, is my original work. This thesis has not been submitted to this or any other institution for the award of any degree or certificate. All sources of assistance and support received during the course of this study have been properly acknowledged.

Henos Ejigu Wondimagegn ____________________ ____________________

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Approval of Dissertation for Defence

We hereby certify that we have supervised, read, and evaluated the dissertation entitled "**Effects of Perceived Linguistic Competence and Textbook Linguistic Complexity on Science Achievement through Engagement Profiles Among Seventh-Grade Students**," prepared by Henos Ejigu Wondimagegn under our guidance. We confirm that the dissertation meets the required academic standards and recommend that it be submitted for oral defense.

Professor Dawit Asrat Getahun

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Approval of Dissertation for Defence Result

As members of the Board of Examiners, we have examined the dissertation entitled "**Effects of Perceived Linguistic Competence and Textbook Linguistic Complexity on Science Achievement through Engagement Profiles Among Seventh-Grade Students**," submitted by Henos Ejigu Wondimagegn. We hereby certify that the dissertation is accepted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Educational Psychology.

Board of Examiners

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Chairperson's Name	Signature	Date
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DEDICATION

To the cherished memory of my sister, Enego Ejigu, whose life was lost to gastric cancer. Her enduring strength and compassion remain a constant source of guidance and inspiration. This work is dedicated to her, with abiding love and remembrance.

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ABSTRACT

Students perceived linguistic competence and textbook linguistic complexity are related to their engagement in science learning, yet the mechanisms linking linguistic factors to achievement remain insufficiently examined, particularly in multilingual contexts. This study investigated the effects of perceived linguistic competence and textbook linguistic complexity on science achievement through engagement profiles among 7th-grade students in Ethiopia. A correlational research design was employed. Data were collected from 500 students for the survey and from 210 students for the linguistic complexity analysis in selected primary schools in Bahir Dar city using multistage, stratified, and content sampling techniques. Perceived linguistic competence across phonological, lexical, and semantic dimensions, perceived textbook linguistic complexity, and engagement profiles across cognitive, behavioural, emotional, and agentic dimensions were assessed using validated instruments. Linguistic complexity of selected reading texts in the 7th-grade General Science textbook was analyzed through a triangulated approach incorporating a Linguistic Complexity Judgment Task, lexical density measures, lexical sophistication, and lexical diversity indices. Science achievement was measured using official second semester average scores. Structural Equation Modeling (SEM) was used to test direct and indirect effects. The findings showed that the reading texts had high lexical density, sophisticated vocabulary, and abstract meanings, indicating a high level of linguistic complexity in the general science textbook. The SEM results also showed that perceived linguistic competence and textbook linguistic complexity had both direct and indirect effects on science achievement through engagement profiles. Engagement profiles partially mediated the effects of perceived linguistic competence and textbook linguistic complexity on science achievement, with cognitive and agentic engagement showing stronger mediating roles. The findings emphasised that linguistic perceptions and text demands influence achievement during a key stage of schooling. It is recommended that science instruction and textbooks be aligned with students' linguistic competence and designed to enhance engagement in order to improve science achievement.

Keywords: *Perceived linguistic competence; textbook linguistic complexity; engagement profiles; science achievement; reading texts*

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ABBREVIATIONS AND ACRONYMS

AGNT	Agentic Engagement
AMOS	Analysis of Moment Structures
AVE	Average Variance Extracted
BEH	Behavioral Engagement
COG	Cognitive Engagement
C.R.	Composite Reliability
CFA	Confirmatory Factor Analysis
EMI	English as a Medium of Instruction
EMOT	Emotional Engagement
EPs	Engagement Profiles
EFA	Exploratory factor analysis
MOE	Ministry of Education
NEAEA	National Educational Assessment and Examinations Agency
NRC	National Research Council
OECD	Organization for Economic Co-operation and Development
PLLC	Perceived Lexical Linguistic Competence
PLC	Perceived Linguistic Competence
PPLC	Perceived Phonological Linguistic Competence
PSLC	Perceived Semantic Linguistic Competence
PTLC	Perceived Textbook Linguistic Complexity
Sci Ach	Science Achievement
SEM	Structural Equation Modelling
SPSS	Statistical Package for Social Sciences

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Science education plays a crucial role in equipping students with natural phenomena, higher-order cognitive skills, and foundational knowledge for future academic and professional pursuits (Osborne, 2013; UNESCO,2024; Vieira & Tenreiro-Vieira, 2016). Science learning during early adolescence constitutes a critical educational priority because this developmental period represents a pivotal stage in cognitive and motivational growth that shapes future learning trajectories (Areepattamannil et al., 2023).

Seventh-grade generally corresponds with early adolescence, a developmental phase marked by rapid cognitive, emotional, and motivational changes. During this period, students' academic identity, their self-perception as learners, undergoes significant consolidation and increasingly predicts subsequent educational outcomes (Destin & Williams, 2020). Empirical evidence indicates that academic achievement at this stage is strongly linked to the development of both academic self-concept and educational identity. Specifically, higher levels of achievement tend to reinforce students' engagement with learning and enhance their perceived academic competence (Hejazi et al., 2009; Hübner et al., 2023).

Longitudinal studies further demonstrate that academic self-concept in early adolescence predicts later engagement, motivation, and achievement, indicating that how students perceive their competence directly shapes their future effort and persistence in school (Hübner et al., 2023; Wu et al., 2021). Importantly, transitions into middle school, which commonly include grade seven, are associated with notable shifts in academic self-concept, making this a sensitive period in which success or failure can meaningfully influence long-term academic trajectories (von Keyserlingk et ai., 2019). Achievement in science at this stage reflects the development of higher-order thinking skills, such as abstract reasoning, problem solving, and metacognition, which depend heavily on students' capacity to process linguistically complex scientific texts and explanations (de los Santos et al., 2025; Pop et al., 2016; UNESCO,2024).

Central to this process is students' ability to engage meaningfully with scientific texts and classroom discourse, as science learning requires learners to observe systematically, formulate questions, generate inferences, make predictions, and analyse evidence through language-mediated science learning (Cairns & Areepattamannil, 2019; National Research Council [NRC], 2012). To grasp academic contents, including knowledge, inquiry, and process skills, students should integrate both cognitive and linguistic abilities (Lesaux et al., 2006; Snow, 2010; Wang & Holcombe, 2010). This integration is particularly essential for understanding the abstract and complex nature of scientific concepts (Seah et al., 2014; Snow et al., 2007). Linguistic elements are fundamental to science education, serving as the primary medium through which scientific knowledge is communicated and learning takes place (Espinet et al., 2012; Haug & Ødegaard, 2014; Shashkevich, 2019).

Student engagement has been consistently linked with positive learning outcomes across educational contexts. Engagement profiles characterised by high cognitive, behavioural, emotional, and agentic involvement are positively related to academic achievement, whereas profiles marked by low engagement are associated with poorer outcomes (Fredricks et al., 2004, Reeve, 2013, 2008; Wang & Eccles, 2013). Engagement profiles reflect both the multidimensional nature of student engagement and the patterns through which it is expressed over time (Bae & DeBusk-Lane, 2019). They encompass the underlying dimensions of engagement, including behavioural, emotional, cognitive, and agentic components, as well as the observable combinations of students' behaviours, emotions, cognitive strategies, and actions in learning contexts (Söderholm et al., 2023).

In science education, holistic engagement supports deeper conceptual understanding, stronger scientific reasoning, higher academic achievement, and greater participation in advanced STEM studies (Ainley & Ainley, 2011; Lee et al., 2016; Sinatra et al., 2015; Wang & Holcombe, 2010). Engaged students are more likely to develop curiosity about scientific phenomena and build meaningful understanding, shaping both their academic experiences and future educational pathways. Engagement profiles are also recognised as indicators of student motivation and are strongly linked to academic success (Fredricks et al., 2004; Reeve & Tseng, 2011). Sustained engagement promotes knowledge retention, higher-order thinking, and success in evolving STEM contexts, while also enhancing students' school experiences and academic identities (OECD, 2019, 2023; Skinner et al., 2016; Xu et al., 2023).

Meaningful learning in science is unlikely to occur without holistic engagement (Xu et al., 2023). Strong engagement deepens students' understanding of subject matter (Wang & Amemiya, 2019), whereas disengagement undermines effective teaching, learning outcomes, and academic progress (Lawson & Lawson, 2020; Lund Dean & Jolly, 2012). Students who are actively engaged demonstrate persistence, curiosity, and willingness to participate in learning tasks (Arnone et al., 2011), and they tend to achieve higher academic performance and experience lower anxiety than disengaged peers (Wigfield & Wagner, 2005).

The amount of time and effort students devote to learning activities is especially salient in science education, a subject that many students perceive as challenging that demand sustained engagement (Ainley & Ainley, 2011). Science learning requires meaningful engagement characterised by active participation, interaction with teachers and peers, and effective use of instructional materials such as textbooks (Hampden-Thompson & Bennett, 2013). Without such positive perceived competence and engagement profiles, students may struggle to understand complex scientific concepts and terminology presented in science instructions (Young, 2005). Accordingly, fostering learning environments that support comprehensive engagement is essential for effective science education and achievement.

In multilingual contexts, using English as the medium of instruction without language-responsive curricula and teaching strategies can limit students' understanding of subject content. Insufficient linguistic support often leads to confusion, frustration, disengagement, and higher dropout rates (Ardasheva et al., 2018; August et al., 2009; McComas, 2013). Research shows that when English instruction lacks systematic language support and scaffolding, learning difficulties increase, particularly in conceptually demanding subjects such as science (Artzi et al., 2022; Seid, 2016; Smit, 2013). Moreover, both perceived and actual language competence strongly influence reading comprehension, a key foundation for academic success (Froiland & Oros, 2014; Kulgemeyer & Geelan, 2024). Students' confidence in their linguistic abilities, along with instructional materials that address relevant language features, therefore plays an essential role in effective learning (Gillen et al., 2011).

Science education is thus inherently linked to linguistic competence and complexity, particularly during early adolescence, when students increasingly depend on textbooks and written explanations to construct scientific understanding (Li & Yang 2022; Snow, 2010; McComas, 2013). At this stage, both students' perceived linguistic competence and the linguistic demands of science textbooks can either facilitate or hinder engagement with scientific content, thereby shaping the development of foundational scientific reasoning and positive learning dispositions essential for future academic achievement (Snow, 2021; Sowmya & Rani, 2025; Wellington & Osborne, 2001).

Phonological, lexical, and semantic dimensions represent key components of linguistic competence that shape students' engagement with and comprehension of science texts, particularly in multilingual instructional contexts. Phonological complexity, including difficult-to-pronounce scientific terms, can hinder decoding and reduce confidence (Fang, 2006), while lexical complexity, characterized by low-frequency, discipline-specific vocabulary and morphological density, increases cognitive demands and may impede understanding (McComas, 2013; Schuth et al., 2017). Semantic complexity, especially when terms carry distinct scientific and everyday meanings, can generate ambiguity and misconceptions, undermining comprehension and engagement (Best et al., 2005; Krajcik & Sutherland, 2010; Wellington & Osborne, 2001). Accordingly, both perceived and actual linguistic competence interact with textbook linguistic complexity to influence students' engagement profiles and science achievement (Snow, 2010; Mithans & Grmek, 2020).

At early developmental stages, students' educational outcomes is often shaped by their ability to comprehend and use language elements and by their perceived linguistic competence and the linguistic complexity of reading texts in learning contexts that could also influence their interest, motivation, and attitudes toward science (Brown & Concannon 2016; McKeown et al., 2018). These early perceptions are significant predictors of sustained engagement, higher achievement, and subsequent participation in STEM fields (Brown & Concannon, 2016; Karabulatova et al., 2013). Perceived competence in linguistic features is particularly important for students to engaging with science texts, where specialized vocabulary and precise language are critical for comprehension (Ardasheva et al., 2021; Snow, 2010).

Stronger self-beliefs and higher perceived linguistic competence are associated with deeper engagement and sustained participation in science learning activities (Zhu et al., 2023; Roebers et al., 2012). Students who perceive themselves as linguistically competent are better able to comprehend and communicate scientific concepts effectively, which supports more active participation in classroom discourse and improved learning outcomes (Badrasawi et al., 2021; Kulgemeyer & Schecker, 2013; Lee & Orgill, 2021; MacKay, 2012). Furthermore, a strong perception of competence can foster positive relationships with teachers, peers, and learning materials, thereby enhancing engagement and achievement (Agwu & Nmadu, 2023;

Pajares & Schunk, 2002). This relationship is particularly noticeable in middle school, where understanding abstract texts and articulating complex ideas require advanced linguistic competence (Luo et al., 2019; Seah, 2016).

Students may be better able to comprehend challenging reading materials when they develop a positive perception of their linguistic competence, which in turn promotes greater participation and deeper understanding. Conversely, low perceived competence often undermines engagement, making it difficult for students to grasp scientific concepts or follow instructions, thereby limiting academic progress (Patall et al., 2018; Wang & Eccles, 2013). Specific weaknesses in phonological, lexical, and semantic domains can exacerbate these challenges. Difficulties with pronunciation of scientific terms reduce confidence and hinder recall, limited vocabulary restricts comprehension and frustrates learners, while ability to interpret complex meanings risk misinterpreting scientific content and disengaging from learning tasks (Duke et al., 2021; Kwakkel et al., 2024; Maton, 2013; Melby-Lervåg et al., 2012*;* Moreton et al., 2017).

Linguistic barriers could contribute directly to students' overall engagements and academic performance, underlying the need to address linguistic competence within science education (Arya et al., 2011; Borodkin & Faust, 2014; Harman et al., 2020; Snow, 2010; Zheng et al., 2024). Research further indicates that high self-perceived linguistic competence is associated with greater interest, involvement, and understanding of scientific terminology (Uchihara & Harada, 2018). In contrast, low perceived competence may result in anxiety, reduced participation, and difficulties in comprehending science texts, ultimately leading to poor academic performance (Jang et al., 2016; Shanahan, 2014). Students who feel more linguistically competent are better equipped to navigate complex textbook language and sustain engagement, whereas excessive linguistic complexity may result in frustration and disengagement (Guthrie et al., 2012).

Students’ perceptions of the complexity of textbook linguistic features may also play a pivotal role in the teaching-learning process in the context of science. If they perceive linguistic features in reading texts as overly complex, they may struggle to effectively engage with the material they use to read, ultimately influencing their science achievement (Amendum et al., 2018; Brown & Concannon, 2016). Students’ low level of competence in linguistic features may limit their ability to understand concepts in the textbook and not actively participate in class discussions with teachers and peers (van der Wilt et al., 2022).

Textbooks continue to hold immense value within educational curricula across many countries, including Ethiopia, despite the proliferation of electronic media and other sophisticated sources of information (Altbach, 2017; Knight, 2015; Mithans & Grmek, 2020). The clarity, quality, and accessibility of textbooks are crucial, as they convey subject knowledge through structured and often complex language features (McComas, 2013; Wellington & Osborne, 2001). When designed, textbooks should be written with clear and accessible language features that simplify complex concepts and should be presented with balanced viewpoints that allow students to critically evaluate different perspectives (Maufiroh et al., 2024; Nadeem & Ostendorf, 2018; UNESCO, 2015).

Textbooks that students can easily interact with are more likely to stimulate interest, commitment, comprehension, and sustained engagement (Graves, 2016; Moschitti & Basili, 2004). Conversely, learning may be hindered when instructional materials are linguistically complex and difficult to comprehend, leading to dissatisfaction, boredom, and disengagement (McComas, 2013; Reed & Kershaw-Herrera, 2016). When students lack sufficient linguistic competence to comprehend textbooks written in English, both engagement profiles and achievement might be diminished (Mithans & Grmek, 2020).

Science textbooks also contain contents that explain scientific concepts, facts, processes, and ideas (Chacón-Díaz, 2022; Fitzgerald et al., 2017; Seah, 2016), and comprehension of reading texts in the textbook is crucial not only for academic success but also for students' future lives (Fitzgerald et al., 2017; Prain & Hand, 2013). Effective science textbooks should employ clear language, align with students' cognitive and developmental levels, and facilitate comprehension of complex concepts (Fang, 2016; Haug & Ødegaard, 2014; UNESCO, 2015). Students' effective acquisition of scientific knowledge is closely linked to their ability to engage with and comprehend reading texts in the textbook, which are often complex due to specialized linguistic features (Li et al., 2022; Snow, 2010; Mithans & Grmek, 2020).

Achievement in science may largely relies on students' ability to decode, interpret, and critically engage with science reading texts in the textbook (Best et al., 2005; Brown & Concannon, 2016; Carlson et al.2003). Unlike everyday language, science reading texts frequently employ terminology that is difficult to pronounce, lexically dense, and conceptually abstract, creating barriers to comprehension and engagement (Ardasheva et al., 2021; Snow, 2010). Prior research shows that the technical and complex linguistic features of science texts can overwhelm learners, particularly middle school students and those from non-dominant language backgrounds whose cognitive and linguistic development may not be sufficient to manage such demands (Fang, 2006; Maufiroh et al., 2024; Snow, 2010; Wellington & Osborne, 2001). Science learning requires considerable effort to construct knowledge from texts containing dense, technical, and abstract language (Guthrie et al., 2017).

Linguistic complexity in science reading texts could impede students' comprehension, reduce engagement profiles, and hinder conceptual understanding during reading, particularly for students with limited language proficiency, thereby negatively affect their science achievement (Schuth et al., 2017; Snow & Uccelli, 2009; Fang, 2006). In contrast, texts with more accessible linguistic features foster behavioural and cognitive engagement and are associated with improved learning outcomes in science (Fang, 2016; Wang & Degol, 2014).

Challenges in processing complex language may also reduce emotional engagement, including students' interest, enjoyment, and perceived competence in science learning (Best et al., 2005; Fang, 2006; McComas, 2013; Snow & Uccelli, 2009; Wang & Degol, 2014).

Scientific literacy requires not only mastery of scientific content but also understanding the linguistic features of science texts (Phillips & Norris, 2009). Difficulties in comprehending these features can reduce engagement and academic achievement. Phonological complexity, such as hard-to-pronounce words and variable stress patterns, may hinder comprehension (Fang, 2006). Lexical complexity, including discipline-specific vocabulary, specialized morphemes, compound words, and derivational forms, further increases cognitive demands (McComas, 2013; Schuth et al., 2017). In addition, semantic ambiguity, where terms have different scientific and everyday meanings, can create misconceptions that weaken comprehension and engagement in science learning (Best et al., 2005; Krajcik & Sutherland, 2010; Wellington & Osborne, 2001).

Linguistic features and contents in science textbooks should also align with the cognitive and developmental level of students and should consider the age and grade level of the intended students (Nankuri et al., 2024; Squires, 2012). Seventh grade often coincides with major educational transitions that heighten learning demands. In many systems, including Ethiopia, it marks a shift to upper primary or middle school, characterised by increased academic expectations, subject specialisation, and greater reliance on textbooks (Scott & Husain, 2021; Seid, 2016; Tytler et al., 2008). This stage frequently follows a transition to English as the medium of instruction, substantially increasing linguistic and cognitive demands (Blankson et al., 2017; Yeniad et al., 2014).

When linguistic demands exceed students perceived or actual competence during this transitional period, frustration, disengagement, and declining achievement are more likely to occur (Guthrie et al., 2012; Jang et al., 2016; Snow et al., 2007; Wellington & Osborne, 2001).

Although previous research consistently underscores the importance of linguistic factors in academic performance generally and in science achievement specifically, the mechanisms through which these factors exert their influence remain underexplored. Studies have demonstrated that both students perceived linguistic competence and textbook linguistic complexity significantly predict academic outcomes (Stone, 1992; Prinsloo et al., 2018; Berman & Cheng, 2010; Soruç et al., 2022). However, limited research has examined how perceived linguistic competence and textbook linguistic complexity jointly influence science achievement via engagement profiles among middle school students in Ethiopia.

Likewise, the effects of early linguistic competence and metalinguistic awareness on achievement have been well-documented (Al-Ahdal & Almarshedi, 2022; Yoğurtçu, 2013), and interventions integrating language support have shown positive effects on science learning (Lee, 2005; Lee et al., 2016). While engagement has been acknowledged as an important predictor of learning behaviours and persistence (Spinath et al., 2006; Soruç et al., 2022), few studies have explicitly examined engagement profiles as mediating mechanism that explain how linguistic factors translate into science achievement. The precise role of engagement in this relationship, how students' motivation, behavioural involvement, and cognitive investment channel the effects of linguistic competence and textbook complexity into measurable achievement, remains insufficiently investigated.

1.2. Statement of the Problem

Globally, student engagement is recognised as a critical predictor of successful learning outcomes, particularly in science education, where understanding abstract concepts and natural phenomena requires sustained cognitive, behavioural, emotional, and agentic involvement (Ainley & Ainley, 2011; Fredricks et al., 2004; Reeve & Tseng, 2011; Wang & Degol, 2014). Meaningful learning relies largely on students' active engagement in inquiry, exploration, and sense-making process, whereas limited engagement leads to fragmented and superficial learning that has substantial consequences for immediate academic performance, long-term academic identity, and educational participation (Getahun & Gebre, 2024; Perry et al., 2022).

Over the past several decades, a substantial body of worldwide research has consistently documented a global decline in adolescents' engagement with science, a trend closely associated with poor learning outcomes (Aker & Ellis, 2019; Bentley, 2024; Salmela-Aro et al., 2021; Vedder-Weiss & Fortus, 2012). Empirical evidence further indicates that multiple dimensions of engagement progressively diminish as students advance from lower elementary through middle school and into high school, indicating a systematic and developmental pattern of disengagement across schooling levels (Hughes et al., 2017; Potvin & Hasni, 2014; Tytler et al., 2008). This declining trend is often manifested in students' reduced investment of time and effort, lower persistence, enthusiasm, and diligence, and is accompanied by persistently poor achievement and performance in science subjects (Dagnew, 2017; Goodman, 2016; Teshome et al., 2022; Zheng et al., 2024).

According to the National Center for Education Statistics [NCES], 2024), science achievement in 2024 dramatically declined compared to recent years, with the largest drops occurring since 2019. Average scores decreased in Physical Science, Life Science, and Earth and Space Sciences, indicating lower overall performance than five years earlier. These declines were most evident among lower- and middle-achieving students, while higher-achieving students showed mixed results across subjects. Compared with 2009, NCES data point to a widening achievement gap: higher-achieving students improved in Physical and Life Science, while lower-achieving students performed worse. In Earth and Space Sciences, performance declined more broadly, with average results remaining below 2009 levels, suggesting a sustained long-term decline (NCES, 2024).

Science achievement is shaped by a complex interplay of factors, including student interest (OECD, 2023), perceived competence and self-efficacy (Bandura, 1993, 1997; Hu et al., 2022), motivation (Areepattamannil et al., 2023), academic engagement (Fredricks et al., 2004; Reeve, 2013), socioeconomic status (Betancur, 2018), teaching quality (Gebre & Polman, 2020), and the language of instruction (Agirdag & Vanlaar, 2018). Among these, low perceived competence and self-efficacy represent significant barriers to pursuing science-related fields, with only about 20% of students reporting confidence and interest in such pathways (Ballen et al., 2017; Blotnicky et al., 2018; Kwon et al., 2023).

In multilingual contexts such as Ethiopia, where English is the primary language of science instruction while students are more proficient in local languages, competence in linguistic features can significantly affect learning outcomes. Perceived competence directly affects students' ability to comprehend scientific texts and to participate meaningfully in classroom discourse (Sigmundsson et al., 2023). Textbook linguistic complexity, including phonological difficulty, lexical density, and semantic abstraction, further challenges comprehension and learning (Norris et al., 2008; Snow, 2010). Together, these factors can hinder reading fluency, conceptual understanding, and classroom engagement, particularly for multilingual learners (Li & Yang, 2022; Mithans & Grmek, 2020).

Science learning could become challenging as students are required to integrate abstract concepts, evidence-based reasoning, and prior knowledge while often facing limited instructional time and support (National Research Council [NRC], 2012). These challenges are amplified in multilingual contexts where early education occurs in local languages before transitioning to English in higher grades (Brock-Utne, 2007; Mavuru & Ramnarain, 2020). Research in Sub-Saharan Africa shows that limited proficiency in the language of instruction and the high linguistic complexity of textbooks hinder engagement and achievement in science (Oyoo, 2017; Mulumba & Masaazi, 2012; Taye, 2025; Webb, 2017). Similarly, UNESCO reports indicate that shifting to English-medium instruction can reduce engagement and academic performance, particularly in linguistically demanding subjects such as science (UNESCO, 2015, 2018, 2021, 2024).

Students whose primary language differs from the language of instruction are at increased risk of poorer learning outcomes, particularly in linguistically demanding subjects such as science (Brock-Utne, 2007; Oyoo, 2017; Yore & Treagust, 2006; Seid, 2016). This risk manifests in increased cognitive load, reduced comprehension of lectures and academic materials due to limited knowledge of discipline-specific terminology and polysemous lexical items with divergent every day and academic meanings (Pun et al., 2024; Soruç et al., 2022; Sweller et al., 2011). Students may also experience limitations in oral expression and written production that discourage participation and promote reliance on rote memorization over deep conceptual understanding (Macaro et al., 2018; Aizawa et al., 2020). These barriers are further intensified by language-related anxiety and reduced self-confidence, which lower classroom interaction, engagement, and achievement.

Cultural mismatches would also arise when scientific concepts lack direct equivalents in students' mother tongues, contributing to exclusion from STEM disciplines (Curle et al., 2020; Lin & He, 2017). In Ethiopia, these problems are particularly pronounced due to the formal transition from mother-tongue instruction in the early grades to English as the medium at the middle school level, typically beginning in Grade 5, Grade 7, or Grade 9 depending on the regional context. This shift often occurs before students have attained sufficient academic proficiency in English, creating substantial barriers to comprehension, particularly in content-heavy subjects like science (Gebele & Anteneh, 2025; Seid, 2016). Consequently, many students face both linguistic and cognitive challenges, which could contribute to disengagement and higher dropout rates in the middle and secondary school levels (Arega et al., 2024; Seid, 2016).

National and empirical studies also consistently report low levels of student engagement and poor achievement in science subjects at this stage (Dagnew, 2017; Eshetie et al., 2025; Moges et al., 2024). Composite scores for grade 8 students stayed below 50% pass mark and dropped from 41.1% to 35.6% across National Learning Assessment (NLA) rounds (Abate and Mishore, 2024). A large proportion of Ethiopian Grade 8 students fail to reach minimum proficiency across core subjects, reflecting systemic weaknesses in foundational learning and instruction, with particularly serious implications for science and mathematics readiness, as evidenced by National Educational Assessment and Examinations Agency [NEAEA] (2020) mean scores of 33.64% in English, 31.14% in Mathematics, 36.07% in Physics, 36.46% in Chemistry, and 38.70% in Biology.

Both perceived and objective textbook linguistic complexity intensify comprehension issues. Students with limited self-assessed competence often view reading texts in textbooks as overwhelmingly complex due to dense and abstract vocabulary, reinforcing disengagement and reliance on superficial learning strategies (Wang et al., 2024). Objectively, readability analyses confirm high complexity in EMI texts, with complex terminologies posing barriers, particularly in multilingual contexts (Bulté & Housen, 2019). This complexity correlates with frustration levels and lower conceptual mastery, as evidenced by cloze tests revealing significant portions of students operating at instructional frustration thresholds (Lo & Lo, 2014; Pun et al., 2024).

Research conducted in Africa and globally has often examined linguistic competence, engagement, or achievement in isolation, relied on simple statistical analysis, or focused primarily on language learning contexts rather than discipline-specific subjects, like science (Charamba, 2023; Homateni Julius et al., 2024; Stoffelsmaet al., 2025; van Pinxteren, 2022). Many of the studies have mainly centred on reading comprehension and general language acquisition outcomes (Qureshi & Al-Surmi, 2025; Snow, 2021; Chen & Abdullah, 2024; Xie

& Curle, 2022). Though there are few studies, many of the findings remain inconclusive. For instance, some studies report that high lexical and semantic complexity increases cognitive load that contributes to frustration and disengagement (Rezaee & Ghanbarpoor, 2022; Stockard et al., 2018), others argue that linguistic complexity can foster deeper engagement and higher-order thinking (Fang, 2006; Guthrie & Klauda, 2012; Xie & Curle, 2022).

Existing research has largely examined the relationship between linguistic factors and academic achievement as a direct one, paying limited attention to the mechanisms through which linguistic variables influence learning outcomes. Student engagement, encompassing cognitive, behavioural, emotional, and agentic dimensions (Fredricks et al., 2004; Reeve, 2013), may be one such mechanism. However, despite its established importance for learning, few studies have investigated its mediating role in the relationship between perceived linguistic competence, textbook linguistic complexity, and science achievement.

Over the past two decades, STEM education has become a key educational priority because of its role in promoting academic development and preparing students for innovation-driven societies (Betancur et al., 2018; Tytler, 2020). Middle school science education is especially important for developing critical thinking, problem-solving skills, and scientific literacy, which are essential for academic success and future STEM participation (Krajcik & Czerniak, 2018; Thomas & Larwin, 2023). As a critical stage in students' cognitive development, middle school provides the foundation for deeper engagement in STEM, and science literacy acquired during this period is a strong predictor of later success in STEM fields (NRC, 2012; Krajcik & Sutherland, 2010; Ng, 2019).

Despite increased emphasis on STEM education, student interest, achievement, and participation in STEM continue to decline globally (Marginson et al., 2013; OECD, 2020; Thomas & Watters, 2015). PISA reported a 14.4-point decline in science scores between 2012 and 2022 and a rise in low-performing students (OECD, 2023), while TIMSS documented declining science achievement in many countries (Martin et al., 2024). Similar trends are evident in Africa, where South Africa's Grade 9 science score fell from 370 in 2019 to 362 in 2023 (DBE, 2024; Wills et al., 2024). In Ethiopia, science achievement remains low, with fewer than 8% of Grade 12 students completing the natural science stream (MoE, 2023; NEAEA, 2020).

This limited empirical evidence, combined with contradictory findings, underline the need for more integrative and context-specific research. Therefore, the central problem addressed in this study is the lack of empirical investigation into the effects of perceived linguistic competence and textbook linguistic complexity on science achievement, mediated by engagement profiles, among seventh-grade students in transitional educational contexts such as Ethiopia, where the shift from mother-tongue instruction to English as the medium of instruction poses a significant linguistic barrier for students' academic success.

1.3. Research Objectives

1.3.1. General objective

The general objective of the present study was to investigate how students perceived linguistic competence and linguistic complexity of 7th-grade General science textbook influence their science achievement through engagement profiles.

1.3.2. Specific objectives

The specific objectives of the present study were:

1. To analyse the linguistic complexity of reading texts in the 7th-grade General science textbook.
2. To examine the relationships among perceived linguistic competence, perceived textbook linguistic complexity, engagement profiles, and science achievement among 7th-grade students.

3. To probe the extent to which perceived linguistic competence and textbook linguistic complexity contribute to the engagement profiles of 7th-grade students.
4. To examine the extent to which perceived linguistic competence and textbook linguistic complexity contribute to the science achievement of 7th-grade students.
5. To investigate the extent to which dimensions of students' engagement profiles mediate the relationship among perceived linguistic competence, perceived textbook linguistic complexity, and science achievement.

1.4. Research Questions

Guided by the conceptual framework, the gaps identified in the literature, and the central research problem, the study sought to answer the following research questions:

1. How linguistically complex are the reading texts in the 7th-grade General Science textbook?
2. Is there a relationship among students perceived linguistic competence, textbook linguistic complexity, engagement profiles, and science achievement?
3. To what extent do the perceived linguistic competence and textbook linguistic complexity have direct effect on engagement profiles among 7th-grade students?
4. To what extent do the perceived linguistic competence and textbook linguistic complexity have direct effect on science achievement among 7th-grade students?
5. How do dimensions of students' engagement profiles mediate the relationships among perceived linguistic competence, perceived textbook linguistic complexity, and science achievement?

1.5. Significance of the Study

The present study examines the influence of linguistic-related factors on students' engagement profiles and science achievement among seventh-grade learners. Specifically, it investigates the relationships among perceived linguistic competence, textbook linguistic complexity, engagement profiles, and achievement in science. By integrating perspectives from Cognitive Load Theory, Self-Determination Theory, and Expectancy-Value Theory, the study aims to advance theoretical understanding of how linguistic factors shape students' motivation, engagement, and learning outcomes in science education. It also seeks to provide empirical evidence on the mediating role of engagement profiles, an aspect that has received limited scholarly attention, particularly in multilingual and transitional educational contexts.

The findings are also expected to contribute to the literature in Science Education, Educational Psychology, and Applied Linguistics by offering an integrated analysis of linguistic competence, textbook language complexity, student engagement, and academic achievement. Practically, the study may inform instructional design and curriculum development by identifying aspects of textbook linguistic complexity that either facilitate or hinder students' comprehension, engagement, and performance. Such insights could assist science educators and textbook developers in designing linguistically accessible and cognitively appropriate instructional materials that support meaningful learning.

In addition, the study may guide teachers in implementing instructional strategies, such as simplifying complex scientific language, providing explicit language support, and using visual and instructional scaffolds to improve comprehension and engagement, particularly for learners transitioning to English as a medium of instruction. At the policy level, the findings may provide evidence to guide curriculum development, teacher preparation, and language-responsive educational policies aimed at enhancing student engagement and science achievement.

More broadly, this study may help address challenges of student disengagement and low academic performance by identifying factors that influence engagement and achievement in science. Improved engagement may foster greater participation in STEM learning and contribute to the development of a scientifically literate and skilled workforce. By focusing on

Ethiopia, where educational conditions differ from many developed contexts, the study may also provide valuable insights into the relationships among students' linguistic perceptions, textbook linguistic features, engagement, and science achievement, thereby extending the existing literature.

1.6. Delimitations of the Study

This study examined how perceived language ability and science textbook complexity influence science achievement through student engagement. It focused on phonological, lexical, and semantic aspects of language competence, as well as perceived and actual textbook difficulty. Student engagement was assessed across cognitive, behavioral, emotional, and agentic dimensions among Grade 7 students in Ethiopia. The study offers insight into the interaction between language-related factors and engagement in shaping achievement, though its findings may not be fully generalizable to other grades, subjects, or contexts.

The findings of this study might be influenced by factors beyond the researcher's control. These include differences in students' prior science knowledge, variations in linguistic competence, classroom dynamics, and the quality of instruction across schools. External factors such as socio-economic status, parental support, and access to learning resources may also affect students' engagement and science achievement but were not directly controlled in the study. In addition, self-reported data on linguistic competence and engagement may be subject to personal bias or social desirability effects.

To ensure a focused and manageable investigation, the study intentionally narrows its scope to Grade 7 general science students in selected Ethiopian schools. The research is limited to seventh-grade students, as this grade represents a critical transitional stage where students face increased academic demands and a shift to English as the medium of instruction, which may influence engagement and learning outcomes.

Due to budget and time limitations, and for ease of access to the study population, the research was conducted in Bahir Dar. The researcher lived in the community and had familiarity with its language, culture, norms, values, and psychosocial context. Prior academic experience in the area also provided insight into local school settings. These factors supported efficient data collection, improved the accuracy of the findings, and may inform future context-based interventions.

1.7. Operational Definitions of Key Terms

The following are operational definitions of key terms or phrases that were used in the study:

Perceived linguistic competence in this study is students' scores on a structured self-report questionnaire measuring their perceived ability to pronounce scientific terms (phonological competence), understand and use scientific vocabulary (lexical competence), and interpret abstract meanings in science texts (semantic competence) (Cresswell, 1988; Fang, 2006; Snow et al., 2007; Guthrie & Klauda, 2012; Tang et al., 2022; Williams et al., 1998).

Textbook linguistic complexity is defined in this study as (a) students' perceived difficulty of the linguistic features in 7th-grade general science textbook reading texts, measured through a structured questionnaire, and (b) the objectively analyzed linguistic features of those reading texts, assessed using multidimensional text-analysis procedures. Higher scores on the perception scale and greater levels of measured linguistic features indicate higher textbook linguistic complexity (Fang, 2006; Guthrie & Klauda, 2012; Laufer, 2013, 2016; Ng et al., 2020; Stockard et al., 2018).

Engagement profiles refer to students' empirically identified patterns of cognitive, behavioural, emotional, and agentic engagement, analyzed as integrated dimensions rather than separate variables. Cognitive engagement involves strategic thinking and self-regulation; behavioural engagement reflects effort, persistence, and participation; emotional engagement includes interest, enjoyment, and belonging; and agentic engagement refers to proactive contributions, such as asking questions and expressing preferences to influence instruction (Fredricks et al., 2004; Reeve & Tseng, 2011).

Science Achievement is students' Semester Average Scores (SAS) in General Science, obtained from second semester official school records. These scores represent the aggregated results of students' performance on tests, assignments, and examinations during the semester and serve as the quantitative measure of their knowledge, understanding, and skills in the subject (National Research Council [NRC], 2012; Caspersen et al., 2017).

1.8. Structure of the Dissertation

This dissertation is organized into six chapters to systematically examine how perceived linguistic competence and textbook linguistic complexity influence students' engagement and science achievement. Chapter one introduces the study, including the background, problem statement, objectives, significance, scope, limitations, and key term definitions. Chapter two reviews relevant literature on science education, student engagement, linguistic competence, textbook complexity, and theoretical frameworks, identifies research gaps, and presents the conceptual framework.

Chapter Three details the methodology, including research design, participants, sampling, instruments, and data collection and analysis procedures. Chapter Four presents the study's results, including descriptive and inferential analyses of linguistic competence, textbook complexity, engagement profiles, and science achievement. Chapter Five interprets the findings in relation to existing research, drawing theoretical and practical insights.

Chapter Six concludes by summarizing key findings, offering recommendations for educators, policymakers, and curriculum developers, and outlining implications for future research. Collectively, this structure provides a clear roadmap for understanding the study's theoretical basis, methodology, empirical results, and contributions to both theory and practice.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2. Introduction

The interplay of perceived linguistic competence, textbook linguistic complexity, and engagement profiles profoundly influences middle school science achievement, particularly in multilingual contexts. Understanding this relationship is therefore essential for developing pedagogical strategies that enhance accessibility, engagement, and equitable learning outcomes in science education. This review investigates the interrelationship among perceived linguistic competence, textbook linguistic complexity, and engagement profiles as critical factors influencing science achievement among middle school students, with particular attention to multilingual educational contexts such as Ethiopia.

2.1. Theoretical Literature Reviews

Language plays a critical role in science education because students' understanding and expression of scientific concepts depend on their linguistic competence. Perceived linguistic competence and textbook linguistic complexity jointly shape learners' engagement and comprehension of scientific content. Engagement profiles may mediate these relationships, making their interaction important for explaining differences in science achievement, particularly among seventh-grade students developing discipline-specific literacy. This theoretical review clarifies the conceptual connections among these constructs and explains how language and engagement influence science learning outcomes.

2.1.1. Conceptualization of competence in educational psychology and linguistics

The term "competence" is a multifaceted and complicated concept in educational psychology and applied linguistics, with its varied interpretations contributing to significant scholarly debate (Klieme et al., 2008). This complexity arises from differing uses across disciplines, often without explicit acknowledgment of these distinctions. Klieme et al. (2008) identify three independent origins of the term in the social sciences: Weber's sociology, Chomsky's linguistic theory, and the functional-pragmatic tradition in American psychology emerging in the late 1950s, which sought to transcend behaviorism and psychometric intelligence research.

In Weber's sociological framework, competence denotes legal responsibility coupled with enforcement mechanisms (Weber, 2009). Conversely, in linguistics and psychology, competence refers to an individual's capability, readiness, and ability within a specific domain of knowledge and skills (Llurda, 2000; Taylor, 1988; Weinert, 2001). While some attribute the term's introduction in these fields to Chomsky (1968), his conceptualization is primarily linguistic and diverges from educational research applications. In educational testing, Messick (1984) defines competence as "what an individual knows and can do in a subject area, however that knowledge and skill are acquired" (p. 217) and, subsequently, as "what a person knows and can do under ideal circumstances" and emphasize the capacity to act, aligning with the notion of context-specific dispositions for achievement acquired through learning (p. 227).

Competence, as a latent construct, is not directly observable but manifests through performance, which serves as its indicator (Klieme et al., 2008; Williams et al., 1998). It is a holistic construct, integrating context-appropriate knowledge, skills, and psychosocial resources, such as attitudes, to accomplish purpose-driven tasks. Competence thus encompasses cognitively controlled abilities and the disposition to solve domain-specific problems, reflected through observable actions (Wiemann & Backlund, 1980; Canale, 1987). Lehmann (2007) further describes competence as a potential, rooted in the ability to exhibit specific behaviors or perform designated activities.

To empirically investigate competence, researchers must design scenarios that elicit performances reflective of the underlying construct (Klieme et al., 2008; Lehmann, 2007).

While performance is not equivalent to competence, it provides a measurable proxy, enabling the assessment of an individual's knowledge and problem-solving capacity within a specific domain of knowledge and skills (Wiemann & Backlund, 1980). This nuanced understanding underscores the importance of distinguishing competence from its observable manifestations in educational and linguistic research.

2.1.2. Origins and evolution of linguistic competence

The concept of linguistic competence has been central to second and foreign language research, evolving from early linguistic theory to its application in education, particularly science learning. This review draws on key theoretical perspectives to explain its development and relevance. The concept originates with De Saussure (1916), who defined it as the underlying capacity for language use. Chomsky (1965, 1968) later distinguished between competence (knowledge of language) and performance (its use in practice), framing competence as a cognitive system within the language acquisition device, with a focus on syntactic structure (Chomsky, 1968). However, this view has been criticized for being too static, as it does not capture the dynamic and evolving nature of language competence, especially among plurilingual individuals (Jensen et al., 2015).

Chomsky's use of "knowledge" as tacit and unarticulated led to the introduction of "cognize" to describe implicit linguistic control (Chomsky, 1968). Hymes (1972) challenged Chomsky's narrow focus on grammatical competence, proposing communicative competence as a broader framework encompassing grammatical, pragmatic, and sociolinguistic dimensions. Communicative competence entails the ability to use language appropriately in authentic socio-cultural and academic contexts (Canale & Swain, 1980; Canale, 1987). This conceptualization has been highly influential in language teaching, emphasizing the integration of linguistic rules with practical application. However, its broad application has led to ambiguity in defining communicative curricula (Moskver, 2006).

In the context of science education, linguistic competence is defined as students' ability to accurately articulate and recognize the phonological features, appropriately use and understand the lexical elements, and meaningfully interpret the semantic structures of scientific language, enabling them to effectively comprehend, express, and communicate scientific concepts (Snow & Uccelli, 2009; Wellington & Osborne, 2001). Scientific communication genres, such as textbooks, lab reports, and presentations, require mastery of specific linguistic features (Nielsen, 2013; Ranawake, 2017). In multilingual contexts like Ethiopia, where English often functions as instructional language, linguistic competence is central for decoding texts, expressing ideas, and engaging in classroom interactions (Bali & Tadesse, 2024).

Linguistic competence is critical for comprehending and communicating scientific concepts and for knowledge transmission (Kulgemeyer & Schecker, 2013). It involves the ability to navigate phonological (pronunciation), morphological (word structure), lexical (vocabulary), syntactic (sentence structure), and semantic (meaning) features of scientific discourse (August et al., 2009; Notina & Bykova, 2017). Students should master specialized scientific vocabulary and complex text structures to engage with scientific content effectively (Moore & Schleppegrell, 2020; NRC, 2012). Linguistic competence also encompasses oral communication skills, such as participating in discussions, presenting findings, and engaging in scientific debates, which foster reasoning and collaborative learning (Roebers et al., 2012).

2.1.3. Theoretical perspectives on linguistic competence

The study of linguistic competence has developed through several theoretical perspectives explaining how language is learned and used in educational contexts. Early linguistic theory, particularly the work of Chomsky (1965, 1968), emphasized the cognitive basis of language through innate grammar, while Hymes (1972) highlighted communicative competence, focusing on appropriate language use in social contexts. Later perspectives emphasized learning through experience and interaction, including usage-based and cognitive approaches (Tomasello, 2003; MacWhinney, 2005), empirically grounded views focusing on measurable skills (Lehmann, 2007), and socio-cultural theory (Vygotsky, 1978; Lantolf & Thorne, 2006), which emphasizes learning through social interaction and scaffolding.

In addition, self-efficacy theory (Bandura, 1997; Pajares, 2003) emphasises the role of learners' beliefs about their abilities in shaping performance. These perspectives can also be interpreted through Cognitive Load Theory (Sweller, 2011), which explains that limited working-memory capacity affects learning, particularly when students must process both subject content and language elements they have not fully mastered. These theoretical frameworks provide a comprehensive understanding of linguistic competence as a multidimensional construct influenced by cognitive, social, and psychological factors, as well as by the cognitive demands involved in learning.

2.1.3.1. Chomsky's generative perspective of linguistic competence

The generative perspective, pioneered by Noam Chomsky (1965), conceptualizes linguistic competence as an innate mental capacity. It refers to a speaker's implicit knowledge of the rules of grammar that enables the generation and comprehension of an infinite number of sentences, including novel ones. Chomsky distinguishes competence from performance, emphasizing the idealized knowledge of language rather than the variability seen in actual use. This approach focuses primarily on syntax and formal grammatical structures, asserting that humans share a universal grammar underlying all languages. Critics argue that it underestimates social, pragmatic, and contextual dimensions of language use.

For Chomsky, linguistic competence is a mental faculty, specifically tied to syntactic well-formedness, governed by an innate language acquisition device (LAD), a cognitive system within the mind/brain that enables humans to acquire and process language (Chomsky, 1968: 2006). The LAD integrates performance systems that access and apply this knowledge, underscoring the critical distinction between knowing a language and using it effectively (Chomsky, 1968, 2006).

Chomsky's perspective posits that linguistic competence is universal and innate, providing the foundation for generating grammatically correct sentences (Chomsky, 1968). In the context of science education, this innate knowledge supports the comprehension and communication of complex scientific ideas by providing the structural basis for language use. However, Chomsky's model has been critiqued for its limitations, particularly its static conception of competence and its focus on tacit, implicit knowledge.

A key criticism concerns the tacit knowledge contradiction. While the term "knowledge" typically implies explicit awareness, Chomsky's notion of linguistic competence refers to an implicit, unconscious understanding of language rules that speakers cannot explicitly articulate. To address this inconsistency, Chomsky (1980: 69) introduced the term cognizing to describe individuals' mental control over their native language structures, emphasizing that this knowledge operates below the level of conscious awareness. Although this neologism sought to resolve the issue, it ultimately highlighted the model's disconnection from practical linguistic usage and application.

A second key critique concerns the static view of linguistic competence. Chomsky's model treats competence as a fixed cognitive state, overlooking its continuous development over time. However, research shows that linguistic competence is dynamic and shaped by ongoing learning and exposure. For example, Jensen et al. (2015) found that plurilingual individuals can develop higher competence in a second language than in their first language. This perspective is particularly relevant in second language acquisition, where competence evolves through interaction and practice. As a result, Chomsky's framework is considered less suitable for empirical research and language teaching, which require models that reflect real-world language development.

2.1.3.2. Hymes's framework of communicative competence

The communicative perspective, pioneered by Dell Hymes (1972), emerged as a direct critique of Chomsky's narrow definition of competence. Hymes argued that linguistic competence must include not only formal know-how about grammar but also the ability to use language appropriately in social contexts; that is, knowing when to speak, how to choose the right form, and how to tailor language according to sociocultural norms. This broader construct, communicative competence, encompasses grammatical, sociolinguistic, discourse, and strategic components that govern meaningful and appropriate interaction rather than abstract sentence structure alone. Functionalists such as Halliday (2003) also emphasize language's social functions and meaning-making roles within communities. From this view, knowledge of rules and structures cannot be separated from context and use; language ability inherently involves the capacity to communicate effectively in real situations.

Communicative competence thus shifts focus from idealized grammar to practices, norms, and communicative effectiveness. For instance, just as syntax regulates phonology and semantics influences syntax, speech rules shape overall linguistic form (Hymes, 1972). Communicative competence encompasses the ability to use language appropriately in diverse situations, combining knowledge of linguistic structures with pragmatic and cultural awareness.

This model has been highly influential in applied linguistics and language pedagogy, particularly in second and foreign language education (Canale & Swain, 1980). Hymes's framework emphasizes the practical application of language, enabling learners to navigate real-world communication effectively. However, its widespread adoption has led to interpretive challenges, with some curricula misaligning with the original intent of a communicative approach (Moskver et al., 2006). Despite these challenges, communicative competence has reshaped language teaching by prioritizing functional language use over mere structural mastery. Chomsky's framework centers on innate grammatical knowledge, treating competence as a mental construct independent of social use, whereas Hymes emphasizes practical language ability, integrating linguistic forms with their communicative functions.

In the context of science education, Hymes's perspective is particularly relevant because it aligns with the need for students to actively understand, use, and perceive linguistic features to engage with scientific texts, discourse, and communication tasks. Hymes provides a more comprehensive framework for how this knowledge is applied in real educational settings, making his model more suitable for analyzing linguistic competence in science learning (Hymes, 1972). This makes Hymes's framework particularly valuable in educational settings, where the practical application of language in disciplines like science is essential for effective learning and discourse.

2.1.3.3. Lehmann's empirically grounded perspective on linguistic competence

Christian Lehmann (2007) presents a theoretical perspective on linguistic competence that seeks to reconcile traditional Chomskyan theory with empirical evaluation. It is an empirically grounded re-conceptualization of linguistic competence that bridges theoretical constructs and measurable language abilities. Lehmann argues that an abstract, idealized speaker-hearer possessing innate grammatical knowledge approach is insufficient for practical and measurable linguistic analysis. He proposes that competence should be conceived as a set of cognitive abilities and skills possessed by real individuals, making it amenable to empirical investigation rather than remaining a purely theoretical construct (Lehmann, 2007.

Lehmann's framework distinguishes between procedural and reflective aspects of competence. Procedural competence refers to the automatic cognitive abilities that enable fluent language use, such as the implicit understanding of grammatical structures and the capacity to generate sentences. Reflective competence, in contrast, involves conscious awareness and the ability to reason about language, such as judging grammaticality or analyzing syntactic patterns. This distinction allows researchers to account for both implicit and explicit dimensions of language knowledge, bridging the gap between internalized rules and observable performance.

Another key feature of Lehmann's perspective is the emphasis on language-specific versus universal components of competence. Universal components correspond to general cognitive capacities and structural features that apply across languages, whereas language-specific components reflect the particular rules, patterns, and conventions of a given language. By differentiating these components, Lehmann provides a framework for comparing native and non-native speakers' competence without assuming that native speakers possess an inherently superior or idealized grammar. His empirical studies, particularly in German, demonstrate that measured linguistic competence is not strictly determined by native speaker status, challenging conventional assumptions in generative theory.

Lehmann advocates for the operationalization of linguistic competence, arguing that it must be assessed through empirically verifiable criteria rather than purely abstract theorization. By devising language-testing regimes capable of capturing both procedural and reflective abilities, Lehmann's approach allows competence to be observed, measured, and compared systematically. This empirical orientation makes his framework particularly relevant for applied linguistics, language acquisition research, and psycholinguistics, providing a bridge between theoretical models and real-world language performance.

2.1.3.4. Vygotsky's Socio-cultural theory

A student's self-assessment of their ability to understand and use academic language effectively, draws on Vygotsky's (1978) socio-cultural theory, which emphasizes that cognitive development is mediated by language and social interaction. Vygotsky's socio-cultural theory (1978) emphasizes that cognitive development is mediated through social interaction, with language serving as the primary tool for learning and thinking.

In the context of science education, students perceived linguistic competence determines how effectively they participate in classroom discussions, collaborative problem-solving, and interactions with scientific texts. Learners who perceive themselves as linguistically competent are more likely to ask questions, articulate ideas, and engage in meaning-making processes, thereby enhancing comprehension and retention.

In contrast, low perceived competence can trigger avoidance behaviors, anxiety, and reduced participation, limiting opportunities for cognitive development. Consequently, socio-cultural theory highlights that students' beliefs about their language ability are critical in mediating access to scientific knowledge. When students perceive themselves as linguistically competent, they are more likely to engage with complex scientific texts actively, employ metacognitive strategies, and persist through cognitively demanding tasks, which, in turn, can enhance science achievement (Guthrie & Klauda, 2014)). Conversely, low perceived linguistic competence may trigger avoidance behaviors, limiting engagement and reducing opportunities for meaningful learning.

2.1.3.5. Self-Efficacy Theory

Self-Efficacy Theory (Bandura, 1977) is central to understanding perceived linguistic competence. According to Bandura, self-efficacy is an individual's belief in their capability to organize and execute actions required to achieve specific goals. Applied to language learning, linguistic self-efficacy reflects learners' confidence in their reading, writing, speaking, and comprehension skills. Higher perceived competence often leads to increased effort, persistence, and engagement in language tasks, while lower perceived competence can result in avoidance or anxiety (Bandura, 1997).

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In educational contexts, self-efficacy influences motivation, persistence, and engagement, shaping how learners approach challenging tasks and cope with difficulties (Schunk & DiBenedetto, 2021). High self-efficacy is associated with greater effort, resilience, and likelihood of completing complex cognitive tasks, while low self-efficacy can lead to avoidance and disengagement. From a perceived linguistic competence perspective, self-efficacy relates to learners' beliefs about their ability to understand, interpret, and produce language effectively in academic contexts (Pajares, 2003; Pajares & Schunk, 2002).

In science education, for example, students' confidence in reading complex texts, using scientific vocabulary, or participating in discussions affects both their engagement and learning outcomes. A student who perceives their linguistic competence as high is more likely to tackle complex explanations, generate hypotheses, or write lab reports, whereas low perceived competence may result in reduced participation or superficial engagement, regardless of actual ability.

2.1.3.6. Contemporary views on linguistic competence

Since Chomsky (1965) and Hymes (1972), the concept of linguistic competence has evolved from structuralist models emphasizing innate grammatical knowledge (Saussure, Chomsky) to dynamic, socially situated frameworks highlighting authentic language use (Hymes, 1972; Pekarek Doehler & Berger, 2018). Chomsky conceptualized competence as an innate syntactic faculty distinct from performance, focused on implicit cognitive knowledge (Chomsky, 1980), whereas Hymes extended it to encompass grammatical, pragmatic, and sociolinguistic abilities necessary for contextually appropriate communication (Canale & Swain, 1980).

Contemporary perspectives define competence as contextually embedded and multimodal, integrating grammatical structures and communicative functions across linguistic levels, empirically validated through interaction (Lehmann, 2007; Matthews, 2006). This synthesis bridges structural and functional approaches, positioning linguistic competence as a flexible cognitive state enabling effective language use. In educational contexts, particularly English-medium science instruction, competence includes phonological, morphological, lexical, syntactic, and semantic mastery to interpret technical vocabulary, analyze complex texts, and communicate scientific understanding (Lee et al., 2009).

However, perceived linguistic competence, individuals' subjective evaluation of their own or others' language abilities, may diverge from objective competence and is shaped by social, cultural, and academic factors (Fernández et al., 2025). Factors such as accent, fluency, and sociocultural norms influence perceptions, often resulting in biased judgments that underestimate actual knowledge (Dragojevic et al., 2017). These perceptions affect classroom interactions and opportunities to participate, as emphasized by Communication Accommodation Theory (Woore, 2018), and significantly impact engagement, willingness to communicate, and academic outcomes (MacIntyre, 2007; Rasheed & Shahzadi, 2021).

Contemporary reconceptualization underlines that linguistic competence cannot be understood exclusively as internalized knowledge; rather, its interaction with perception mediates learners' participation and academic achievement, emphasizing the need for pedagogical strategies that address both actual and perceived abilities. Perceived linguistic competence significantly influences engagement, as learners' willingness to communicate often correlates more strongly with perceived than with actual competence (MacIntyre, 2007).

Negative perceptions, whether held by peers, instructors, or learners themselves, can restrict participation and learning even when underlying knowledge is strong.

In science education, deviations in pronunciation or lexical use may result in underestimations of students' conceptual understanding (Rasheed & Shahzadi, 2021), a phenomenon especially pronounced for multilingual learners whose abilities are frequently evaluated through biased social perceptions rather than true linguistic and disciplinary competence (Woore, 2018). Thus, perceived linguistic competence functions as a critical mediator between actual ability and academic outcomes.

2.2. Conceptualization of Linguistic Complexity

The concept of linguistic complexity is inherently multifaceted and elusive, characterized by vague and varied definitions across disciplines. The Oxford Dictionary of English (2010), for example, defines complexity as the state of being "intricate," "sophisticated," or "complicated," often associated with difficulty. This lack of definitional clarity, compounded by the multidimensional nature of complexity, poses challenges in its operationalization, particularly in applied linguistics and science education (Bulté & Housen, 2019). Linguistic complexity manifests at multiple levels (e.g., word, phrase, sentence) and across various dimensions (e.g., lexical, phonological, semantic,), rendering consistent measurement difficulty and limiting the comparability of research findings (Căprioară & Răduț-Taciu, 2021).

Linguistic complexity is broadly understood as the number and variety of elements within a linguistic system and the elaborateness of their interrelations (Bulté & Housen, 2019). It encompasses features that make communication either simpler or more challenging, depending on context. However, the absence of a unified definition or standardized measures complicates its study (Căprioară & Răduț-Taciu, 2021). In second language acquisition (SLA) and science education, complexity is often interpreted quantitatively, focusing on the number, variety, and interactions of linguistic elements, such as phonological difficulty, lexical diversity (range of words), density (proportion of lexical words), and sophistication (use of less frequent words), semantic (abstractness or ambiguity of words), syntactic intricacy (sentential, clausal, phrasal), or morphological variation (inflectional, derivational) dimensions (Fang, 2016; Fitzgerald et al., 2017; Green, 2019; Shen et al., 2023).

In science teaching and learning, several features contribute to linguistic complexity. Scientific discourse relies heavily on specialized and abstract vocabulary, which increases lexical and conceptual demands for learners (Duschl & Grandy, 2013). The need for precision in scientific terminology, often expressed through nominalization and specific referential use, results in dense and syntactically complex constructions (Thompson & Mulac, 1991). In addition, science texts frequently employ subordinate and embedded clauses to describe relationships among variables and processes, which increases processing load and may hinder comprehension (Snow, 2010). As a result, domain-specific vocabulary and complex sentence structures together raise the linguistic demands placed on learners in scientific texts.

To address the polysemy of complexity, this study adopts a descriptive approach that defines linguistic complexity as the level of difficulty or sophistication in language features such as lexical, phonological, and semantic elements in science textbooks or discourse. It denotes the challenge such features pose for learners and is measured through commonly used metrics, for example, pronunciation difficulty, vocabulary breadth and width, abstractness of meanings, while acknowledging that quantitative indicators alone do not exhaustively represent textual complexity. Perceptual and cognitive dimensions, learners' perceptions of abstraction or ambiguity, and working-memory demands, also shape experienced complexity (Cheng & Dörnyei, 2007).

The definition focuses on structural and textual manifestations rather than theoretical explanations of complexity. This approach deliberately excludes theoretical assumptions about the causal mechanisms or conditions under which complexity increases, decreases, or remains stable rather a relationship that many accounts of linguistic complexity implicitly or explicitly acknowledged (Szmrecsanyi & Kortmann, 2012). Linguistic complexity can be measured using indicators such as sentence length, clause density, and vocabulary size, but these metrics do not fully capture its multidimensional nature because they overlook learners' cognitive and perceptual demands (Cheng & Dörnyei, 2007). Factors such as difficult pronunciation, abstraction, ambiguity, figurative language, and processing load also contribute to perceived complexity, which is particularly relevant in science education where students must interpret dense texts and specialized discourse to understand and communicate scientific concepts (Utami & Muliastuti, 2024).

2.2.1. Theories and conceptualization of linguistic complexity in educational texts

Early research on textual complexity emerged from mid-twentieth-century readability studies. Flesch (1948) and Dale and Chall (1948) developed formulas that estimate text difficulty using surface features such as sentence length and word familiarity. For instance, the Flesch Reading Ease formula calculates difficulty based on sentence length and syllables per word, whereas the Dale–Chall readability formula uses lists of familiar vocabulary to assess lexical difficulty. These models assume that longer sentences and less familiar words increase cognitive demands on readers. However, readability formulas account only for surface features and do not capture hierarchical syntax, discourse cohesion, or conceptual abstraction. Consequently, they provide only a partial measure of linguistic complexity in textbooks (Flesch, 1948; Dale & Chall, 1948).

A significant development in the study of written discourse complexity was introduced by Jean Ure (1971), who proposed lexical density as a key distinguishing feature between spoken and written language. Ure defined lexical density as the proportion of lexical (content) words to the total number of running words in a text. Ure demonstrated empirically that written texts typically display higher lexical density than spoken discourse, reflecting greater informational packaging per clause. This insight is particularly relevant for textbook analysis, as academic textbooks characteristically exhibit high lexical density. Ure's contribution bridges surface readability metrics and later functional accounts by highlighting how informational concentration contributes to perceived complexity.

A more structurally grounded account of linguistic complexity is found in generative linguistics. Noam Chomsky (1965, 1968) conceptualized language as a system of hierarchical structures generated by underlying rules rather than linear sequences. Within this framework, complexity arises from syntactic embedding, recursion, and transformational operations, where sentences with multiple subordinate clauses or long-distance dependencies require deeper structural representation and greater processing effort. For example, center-embedded clauses interrupt incremental parsing and increase memory load. In scientific and technical textbooks, features such as nominalization and clause embedding often increase syntactic density even when sentence length remains relatively short.

Systemic Functional Linguistics (Halliday, 2009) offers a complementary perspective by viewing language as a resource for meaning-making. Halliday highlighted lexical density and introduced grammatical metaphor, showing how experiential processes are transformed into abstract nominal forms in academic discourse, for example, “When water evaporates, it cools the surface” can be reformulated as “Evaporation causes cooling.” Such reformulation increases lexical density and condenses causal relations into nominal groups (Halliday, 2009). Written academic language is thus marked by high lexical density and complex nominal structures, which contribute to perceived difficulty. In textbook analysis, grammatical metaphor and informational condensation serve as key indicators of linguistic complexity, reflecting the compression of processes into abstract entities.

Psycholinguistic research further clarifies the relationship between structural features and perceived difficulty by examining real-time language processing. Just and Carpenter (1992) proposed a capacity theory of comprehension, arguing that individual differences in working memory capacity influence the ability to process syntactically complex sentences. This model demonstrates that structures involving multiple embeddings or long-distance dependencies impose measurable cognitive burdens. Linguistic complexity judgments therefore correlate with processing effort, linking formal structure to working memory constraints (Ferla et al., 2010).

Educational psychology contributes an additional perspective through Cognitive Load Theory. Sweller (2011) distinguishes among intrinsic load, extraneous load, and germane load. In textbook contexts, linguistic complexity often increases extraneous cognitive load when dense syntactic constructions or excessive abstraction hinder comprehension independently of conceptual difficulty. If learners must allocate substantial working memory resources to decode linguistic form, fewer resources remain available for schema construction and integration. From this perspective, linguistic complexity judgment tasks can function as evaluative tools for identifying whether textbook language unnecessarily burdens learners' cognitive systems.

Usage-based theories, advanced by Bybee (2006) and Tomasello (2003), further complicate purely structural accounts by emphasizing the role of frequency and experience. According to their views, linguistic representations emerge from repeated usage events, and frequent constructions become cognitively entrenched. Consequently, structures that are statistically common within academic discourse may be processed more efficiently despite their structural density. Conversely, rare constructions may be perceived as complex even when they are syntactically simple (Bybee, 2006; Tomasello, 2003).

Register theory and corpus-based approaches underscore that complexity is socially situated. Biber (1992) demonstrated that linguistic features cluster systematically according to communicative purpose and discourse domain. Academic textbooks typically exhibit high informational density, technical vocabulary, impersonal stance, and frequent nominalization (Biber, 1992). These features reflect the communicative demands of disciplinary knowledge construction than arbitrary stylistic choices.

Despite their widespread use, readability formulas have been criticized for oversimplifying the complexity of academic texts. Many scientific and educational texts contain relatively short sentences yet remain difficult to understand due to technical terminology, conceptual abstraction, and dense informational packaging. As a result, formula-based readability measures often underestimate the difficulty of disciplinary texts (Lodge, 2021; Strohmaier et al., 2023).

Contemporary readability research therefore incorporates insights from cognitive psychology, discourse analysis, and computational linguistics. Modern approaches consider not only surface-level linguistic features but also deeper aspects of textual organization, including cohesion, conceptual density, and inferential demands. This broader perspective recognizes that readability emerges from the interaction between textual features and readers' background knowledge, motivation, and cognitive capacity (Kintsch, 1998; Crossley et al., 2016). Linguistic complexity judgment tasks are therefore appropriate and shaped not only by formal properties but also by learners' exposure to and familiarity with academic registers.

2.2.2. Frameworks of Linguistic complexity in educational reading texts

Linguistic complexity in educational reading materials has received extensive scholarly attention because of its direct influence on students' comprehension, disciplinary literacy, and academic achievement. Educational texts frequently present dense conceptual information that requires readers to process vocabulary, sentence structures, and conceptual relationships simultaneously. This challenge is particularly evident in science textbooks, where specialized terminology and abstract explanations are commonly used to represent scientific knowledge.

Given the multidimensional nature of linguistic complexity, contemporary research increasingly advocates integrative approaches for analyzing educational texts. These approaches combine theoretical insights from linguistics, disciplinary literacy, and cognitive psychology with empirical methods such as computational text analysis and learner-based evaluations. Integrating these perspectives enables researchers to identify specific linguistic features that contribute to comprehension difficulties and to understand how these features interact with learners' linguistic and cognitive capacities.

Studies in applied linguistics and educational research indicate that the linguistic demands of instructional materials significantly influence learners' ability to access and interpret academic content (Bulté & Housen, 2019; Crossley et al., 2012; Ortega, 2015). Consequently, several theoretical frameworks have been developed to explain how linguistic complexity operates in educational reading contexts and provide a more comprehensive basis for examining the accessibility of educational reading materials and for improving the design of instructional texts (Bulté & Housen, 2019; Crossley et al., 2019).

2.2.2.1. Learner's linguistic complexity judgment task (LCJT)

The present study is theoretically grounded in three complementary aspects of research that together explain how lexical complexity affects reading comprehension in textbooks, engagement, and achievement, and how such complexity can be empirically identified through learner response patterns. These perspectives include Lexical Threshold Theory, learner-based assessments of linguistic complexity, and psycholinguistic models of reading. Together, they form a cognitive and empirical framework explaining why words identified as difficult by 40%, 50%, or 70% of learners can be considered meaningfully complex in middle-school disciplinary texts (Fang, 2006; Ng et al., 2020).

When at least 40% of students identify words as complex, the text is considered linguistically demanding; when this applies to 50% of the words in a reading text, it indicates majority-level linguistic complexity; and when 70% of students agree, it reflects strong consensus, signaling terms likely to hinder engagement and comprehension in scientific texts (Fang, 2016; Laufer, 2013, 2016; Ng et al., 2020). Using 40%, 50%, and 70% agreement levels operationalizes Lexical Threshold Theory at the word level in age-appropriate materials, providing an empirical basis for classifying vocabulary difficulty and aligning with systematic approaches to identifying complex scientific terminology (Cheng et al., 2021; Ng et al., 2020).

Lexical Threshold Theory establishes that comprehension depends on maintaining sufficiently high lexical coverage (Laufer, 2013, 2016). According to Laufer (2013), readers must know a substantial proportion of the words in a text to achieve functional understanding, particularly in academic contexts. Laufer (2016) further demonstrates that lexical text coverage and learners' vocabulary size strongly predict reading outcomes, and that insufficient coverage can hinder comprehension by disrupting inferencing, cohesion, and conceptual integration. For middle school textbooks, this is especially significant, as students encounter domain-specific and low-frequency terms, such as technical vocabulary in physics, biology, or chemistry, that carry essential conceptual meaning (Pilán et al., 2016).

Learner-based evaluation research further supports the methodological validity of eliciting student judgments to identify linguistic difficulty. Studies show that learners can reliably assess linguistic complexity under structured conditions, and that their judgments correlate with computational indices of lexical and syntactic complexity (Crossley et al., 2012, 2014, 2016). While many learner-based tasks assess text-level difficulty, applying this approach to word-level identification isolates specific lexical triggers of perceived complexity (Alfter, 2021). Psycholinguistic processing models offer a cognitive explanation for why certain scientific words are repeatedly perceived as complex.

Reading comprehension depends on coordinated decoding, vocabulary knowledge, and semantic integration, all of which can be strained by unfamiliar vocabulary (Rayner & Duffy, 1986; Rayner et al., 2012). Lexical Threshold Theory links vocabulary coverage to comprehension (Laufer, 2013, 2016). Research shows that scientific texts impose high lexical demands on middle-school learners (Ng et al., 2020), and both learner-based evaluations and structured analyses support systematic assessment of linguistic difficulty (Crossley et al., 2014, 2016; Cheng et al., 2021). Together, these perspectives explain how vocabulary complexity affects seventh-grade comprehension and how it can be measured using defined thresholds.

2.2.2.2. Halliday's theory of scientific language and Ure's contribution to linguistic complexity

Halliday's theory of scientific language, developed within the framework of systemic functional linguistics (SFL), provides a foundational explanation of how disciplinary knowledge is constructed through language. Central to this theory is the view that linguistic complexity is not incidental but functional, arising from the communicative demands of scientific inquiry, which requires abstraction, generalization, and cumulative knowledge building (Halliday, 2009). Scientific language, from this perspective, represents a specialized semiotic system that differs qualitatively from everyday discourse.

This view builds directly on earlier functional accounts of language variation, most notably Ure's (1971) work on lexical density and register variation. Ure demonstrated that different communicative contexts give rise to systematic differences in linguistic organization, particularly in the proportion of content words to grammatical words. She argued that written and informational texts, especially those associated with education and science, exhibit significantly higher lexical density than spoken or everyday language. This insight provided one of the earliest empirical foundations for understanding linguistic complexity as a context-sensitive and register-dependent phenomenon, rather than a purely structural one.

Halliday extends and theoretically elaborates Ure's observations by embedding lexical density within a broader model of meaning-making. In Halliday's account, scientific texts are characterized by several interrelated features that collectively increase linguistic complexity.

Foremost among these is grammatical metaphor, particularly nominalization. Through grammatical metaphor, processes and relations that would typically be expressed congruently as clauses or verbs are reconstrued as nouns or nominal groups. This allows scientific discourse to condense dynamic processes into stable entities that can be classified, compared, and manipulated within extended chains of reasoning (Halliday, 2009).

The widespread use of nominalization directly contributes to the high lexical density first identified by Ure (1971). By compressing processes and qualities into nominal forms, scientific texts pack more lexical meaning into fewer clauses, increasing semantic load while reducing syntactic explicitness. Empirical studies of textbooks confirm that lexical density rises sharply as texts move from everyday explanation to scientific exposition, a shift that has been shown to correlate with increased comprehension problems (Fang, 2005). Ure's original metric of lexical density thus remains theoretically relevant, but Halliday's framework explains why such density emerges and how it functions epistemologically in scientific discourse.

In addition to dense lexical packing, scientific language foregrounds abstract participants and processes rather than concrete, human actors. Concepts such as systems, variables, reactions, or forces function as grammatical subjects, enabling the generalization and decontextualization required for scientific knowledge construction. While this abstraction enhances explanatory power, it also obscures agency and temporality, increasing interpretive demands on readers, particularly those who have not yet mastered disciplinary conventions (Schleppegrell, 2004).

Halliday further argues that logical relations in scientific discourse are frequently realized through clause complexes and grammatical structures, rather than through explicit conjunctions (Halliday, 2009). Causal, conditional, and consequential relationships are embedded within grammatical patterns, requiring readers to infer connections that would be overtly signaled in everyday language. This implicit realization of logic intensifies what

Halliday describes as semantic density, while simultaneously reducing grammatical congruence. Ure's work anticipated this distinction by noting that written informational texts rely less on explicit interactive cues and more on internally structured meaning, a feature that contributes to their perceived difficulty (Ure, 1971).

Halliday's and Ure's contributions offer a coherent theoretical explanation for why scientific texts are systematically more complex than everyday language. Ure provides an early empirical identification of lexical density as a key marker of informational load, while Halliday situates this feature within a comprehensive theory of language as a resource for meaning-making in disciplinary contexts. Research applying these insights to textbook analysis has consistently shown that such linguistic features reliably distinguish scientific discourse from common-sense language and are strongly associated with learner comprehension challenges (Fang, 2005; Schleppegrell, 2004).

2.2.2.3. Lexical sophistication and TAALESS

Lexical sophistication constitutes a central and empirically well-established dimension of linguistic complexity, particularly in relation to reading difficulty and language proficiency. Early work by Laufer and Nation (1995) demonstrated that readers' comprehension is strongly constrained by the proportion of low-frequency and specialized vocabulary in a text, showing that lexical difficulty is not merely a surface feature but a primary determinant of processing load. Subsequent research has consistently confirmed that texts containing less frequent, more abstract, and morphologically complex lexical items impose greater cognitive demands on readers, especially second language learners and novice disciplinary readers (Kyle et al., 2018).

From a theoretical perspective, lexical sophistication reflects the extent to which a text draws on vocabulary that is uncommon in general language use but typical of academic and disciplinary registers (Gonzalez, 2013; Higginbotham & Reid, 2019). Such vocabulary often encodes abstract concepts, technical processes, and condensed meanings, making it essential for knowledge construction while simultaneously increasing interpretive difficulty. This dual role positions lexical sophistication as a key mechanism through which linguistic complexity functions in educational texts.

The Tool for the Automatic Analysis of Lexical and Semantic Sophistication (TAALESS) provides a computational means of operationalizing this construct with empirical precision. TAALESS quantifies lexical sophistication through multiple indices, including frequency-based measures (how often words occur in large reference corpora), range-based measures (the dispersion of words across registers or texts), and psycholinguistic indices (such as concreteness, familiarity, and age of acquisition). These measures are derived from large, well-established corpora, allowing lexical properties to be assessed in a transparent and replicable manner (Kyle et al., 2018).

Validation studies have demonstrated that TAALESS indices reliably discriminate between texts written for different proficiency levels and across a range of educational genres, including academic prose, instructional materials, and learner-produced texts (Kyle & Crossley, 2017). Importantly, these findings are not limited to isolated lexical features; rather, they show that aggregated lexical sophistication metrics systematically pattern with known differences in textual difficulty and reader proficiency. This empirical robustness supports the use of TAALESS as a reliable tool for large-scale analysis of lexical complexity.

Crucially, lexical sophistication as operationalized by TAALESS aligns closely with Halliday's notion of lexical density in scientific discourse. Halliday argues that scientific texts achieve semantic compression by packing meaning into dense lexical items, often realized through nominalization and technical vocabulary (Halliday, 2009). While Halliday conceptualizes lexical density as a functional property of discourse rather than a numerical metric, TAALESS provides a computationally testable instantiation of this theoretical construct. By quantifying the frequency, abstractness, and distributional properties of lexical items, TAALESS captures the degree to which a text relies on dense, specialized vocabulary to construct meaning.

2.2.2.4. Textual cohesion, semantic integration, and TAASCO

Textual cohesion refers to the degree to which meaning is explicitly signaled and interconnected across clauses, sentences, and larger discourse units through linguistic devices such as lexical repetition, semantic overlap, reference, and connectives. Within theories of discourse processing, cohesion is understood as a critical factor shaping how readers construct mental representations of texts, as it influences the ease with which ideas can be integrated into a coherent situation model (Crossley & McNamara, 2016).

Importantly, cohesion is not a unidirectional indicator of textual quality or difficulty. Research in discourse comprehension has consistently shown that high levels of explicit cohesion facilitate understanding for novice or low-knowledge readers, as cohesive cues reduce the inferential burden required to establish relationships between propositions. In contrast, low-cohesion texts are a defining characteristic of expert discourse, including scientific and academic writing, where readers are expected to supply missing links based on prior knowledge and disciplinary expertise (Crossley & McNamara, 2016). Scientific texts often omit explicit connections, relying instead on shared conceptual frameworks, technical terminology, and abstract representations to convey meaning efficiently.

The Tool for the Automatic Analysis of Semantic Cohesion (TAASCO) provides a computational framework for systematically measuring these cohesion-related properties of texts. TAASCO operationalizes textual cohesion through a wide range of indices, including semantic overlap between adjacent and distant sentences, similarity of argument structures, and the distribution of explicit connectives signaling logical relations (Crossley et al., 2019). These indices are derived using corpus-based semantic models, allowing cohesion to be quantified in a replicable and theoretically interpretable manner.

Empirical validation studies demonstrate that TAASCO measures are sensitive to differences in genre, proficiency level, and communicative purpose. Specifically, TAASCO indices have been shown to predict reading comprehension outcomes and to interact systematically with reader characteristics such as background knowledge and language proficiency (Crossley et al., 2023). For example, texts with lower semantic overlap may hinder comprehension for novice readers while posing fewer challenges for expert readers who can rely on domain knowledge to infer implicit connections. These findings support the view that cohesion is best understood as a reader–text interaction phenomenon, rather than as an inherently facilitative or obstructive textual property.

TAASCO's focus on implicit and explicit meaning relations aligns closely with Halliday's account of scientific discourse, in which logical relations are frequently realized through grammatical structures rather than overt cohesive markers. Halliday argues that scientific texts achieve semantic density by embedding relationships within clause complexes and nominal groups, reducing surface cohesion while increasing conceptual complexity (Halliday, 2009). TAASCO provides a computational means of examining this theoretical claim by quantifying the degree to which semantic connections are explicitly marked or implicitly constructed across a text.

In this way, TAASCO extends Halliday's functional insights by enabling empirical investigation of discourse-level complexity. When used alongside lexical sophistication measures, TAASCO allows researchers to distinguish between texts that are difficult because they contain dense, specialized vocabulary and those that are challenging because they require readers to infer unstated semantic relationships. Together, these tools provide a more comprehensive account of linguistic complexity in educational texts, particularly in scientific discourse where abstraction, condensation, and implicit meaning are central to knowledge construction.

2.2.2.5. Corpus-driven analysis of linguistic complexity in science textbooks

The linguistic complexity of science textbooks has been widely recognized as a central factor influencing students' comprehension, disciplinary literacy development, and conceptual learning (Arya et al., 2011). Early investigations of textbook difficulty relied heavily on readability formulas developed by Flesch (1948) and Dale and Chall (1948). These formulas operationalized difficulty primarily in terms of mean sentence length and word familiarity. Although such measures provided quantifiable indices and were widely adopted in educational publishing, subsequent research demonstrated that readability formulas often underestimate the complexity of science textbooks because they do not account for phonological complexity, conceptual density, technical vocabulary, and abstractness of terminologies.

Corpus-based register analysis contextualizes science textbook language within disciplinary norms. Biber et al. (2011) demonstrate that linguistic features cluster systematically according to communicative purpose. Scientific registers are characterized by high informational density, technical vocabulary, nominalization, and reduced personal reference. Tools for lexical sophistication and cohesion analysis operationalize these register-specific characteristics, enabling systematic comparison across grade levels, disciplines, and curricula. Khojasteh and Mukundan (2025) provide a systematic review of corpus-based methodologies applied to textbook analysis and evaluation, examining 29 peer-reviewed studies from 2010 to 2024. Their work emphasizes how corpus-based analysis allows researchers to uncover linguistic patterns at multiple levels, including lexical, syntactic, and semantic features.

The review emphasizes that corpus methods are effective even with small datasets, such as a single paragraph, when the goal is to identify patterns, frequency distributions, or collocational tendencies. For instance, analyzing the occurrence of specific grammatical structures or vocabulary items can reveal whether a text reflects authentic language use or meets learning objectives. Tools like AntConc or COCA provide both qualitative and quantitative insights from small samples, enabling evidence-based textbook evaluation and instructional design (Khojasteh & Mukundan, 2025). This approach allows educators to make precise adjustments without relying on large corpora, demonstrating that corpus-based analysis is scalable for large datasets while remaining sensitive enough to extract meaningful insights from minimal text segments.

By analyzing limited textual units, researchers can detect syntactic patterns and lexical choices that either facilitate or hinder comprehension. This approach is justified because modern corpus tools provide automated counts, statistical comparisons, and visualization of patterns, enabling rigorous evaluation even in data-limited contexts. Khojasteh and Mukundan (2025) show that corpus analysis can reveal both large-scale trends and paragraph-level insights, while Durkee (2020) provide empirical evidence that even small textual units contain analyzable patterns that reflect syntactic complexity and academic preparedness. This underscores a central principle: corpus-based evaluation does not require extensive corpora to be valid or informative. Instead, carefully designed analyses of even a few words or sentences can yield actionable pedagogical insights, guiding textbook design and learner support with precision and reliability.

2.2.2.6. Integrative and Triangulated Perspective on Linguistic Complexity

The combined application of the Linguistic Complexity Judgment Task (LCJT), Halliday’s theory of scientific language, TAALESS, and TAASCO represents a methodologically robust and theoretically coherent approach to the analysis of linguistic complexity. Rather than treating complexity as a single measurable property, this integrative framework recognizes linguistic complexity as a multidimensional construct that emerges from the interaction between textual features, disciplinary conventions, and reader processing. Such a perspective is consistent with contemporary views in applied linguistics, which emphasize that no single analytic lens can adequately capture the full range of factors contributing to textual difficulty.

Within this framework, LCJT provides direct access to learner-perceived complexity, capturing how readers experience and evaluate the overall difficulty of texts. These judgments reflect the cumulative effect of multiple linguistic dimensions operating simultaneously during reading. However, learner perceptions alone cannot reveal the specific linguistic mechanisms responsible for difficulty. For this reason, LCJT findings are interpreted in conjunction with theory-driven and computational analyses that offer explanatory depth.

Halliday's theory of scientific language supplies the necessary theoretical grounding for interpreting complexity in disciplinary texts. By conceptualizing scientific language as a functional semiotic system characterized by lexical density, grammatical metaphor, abstraction, and implicit logical relations, Halliday's framework explains why certain linguistic patterns systematically increase processing demands for learners. This theoretical lens ensures that observed patterns are not treated as isolated features but are understood in relation to the epistemic goals of scientific discourse.

TAALESS and TAASCO complement this theoretical foundation by providing computationally verifiable indicators of linguistic complexity at different levels of analysis. TAALESS quantifies lexical sophistication, enabling precise measurement of the frequency, abstractness, and distribution of lexical items that contribute to semantic density. TAASCO, in turn, captures discourse-level complexity by measuring semantic cohesion and the extent to which meaning relations are explicitly or implicitly signaled across a text. Together, these tools operationalize key Hallidayan constructs and translate them into measurable indices suitable for systematic empirical investigation.

This triangulated approach directly addresses long-standing critiques in linguistic complexity research that highlight an overreliance on single-dimension metrics or purely computational measures divorced from theory and learner experience (Bulté & Housen, 2012; Ortega, 2015). By integrating learner-based evaluations, functional linguistic theory, and automated text analysis, the framework enhances construct validity, strengthens interpretive rigor, and allows findings to be corroborated through converging evidence. As a result, the analysis moves beyond descriptive measurement toward a theoretically informed and empirically robust account of linguistic complexity in educational texts.

2.3. Conceptualization of Student Engagement Profiles in Education

Student engagement, a multidimensional construct, is primarily conceptualized through two frameworks. The first one is Fredricks et al. (2004) North American model and the second one is Schaufeli et al. (2002) European engagement approach (Alrashidi et al., 2016; Upadyaya & Salmela-Aro, 2013). The first model delineates engagement into behavioral (e.g., attendance, norm adherence, task participation), cognitive (e.g., strategic learning, problem-solving), and emotional (e.g., positive attitudes, motivation, belonging) dimensions (Fredricks et al., 2004). In contrast, the second model emphasizes psychological engagement, comprising vigor (energy, positive approach), dedication (enthusiasm, commitment), and absorption (task concentration), prioritizing internal motivational states over observable behaviors (Schaufeli et al., 2002; Upadyaya & Salmela-Aro, 2013).

Conceptual overlaps include cognitive engagement aligning with dedication, vigor with emotional engagement's positive affect, and absorption with behavioral engagement's task focus (Tuominen-Soini & Salmela-Aro, 2014). However, the second model omits behavioral aspects like attendance and peer/teacher relationships, limiting dedication to study-related feelings (Upadyaya & Salmela-Aro, 2013). Recent scholarship introduces agentic engagement, emphasizing students' proactive role in shaping learning environments through suggestions and initiated opportunities, driven by self-efficacy and linked to enhanced skills, grades, and achievement (Reeve & Tseng, 2011; Reeve, 2013; Reeve & Lee, 2014).

Adapted from organizational contexts, student engagement frames academic activities as work-like tasks aimed at goals like achievement or degree attainment (Reschly & Christenson, 2012). Grounded in constructivism, it underscores active learning, where engagement is critical for meaningful outcomes (Skinner & Pitzer, 2012). Engagement manifests through positive attitudes, effective communication, and investment in purposeful activities (Schaufeli, 2013). It serves three functions, such as enabling learning, supporting development, and reflecting teachers' motivational efforts (Reeve, 2013). Highly engaged students exhibit greater focus, effort, and performance, reducing dropout rates and enhancing well-being (Lei et al., 2018; Boulton et al., 2019).

Engagement in education is conceptualized as a multidimensional construct that operates at macro (institutional), meso (patterns of study and participation), and micro (task-specific learning activities) levels, and it may be understood as a process, an outcome, or an indicator of the quality of students' effort (Wiseman et al., 2016). In higher education research, Kuh (2003) defined engagement as the time and energy students devote to educationally meaningful activities and the institutional policies and practices designed to promote such participation. Engagement profiles describe the multidimensional and time-evolving nature of student engagement by integrating behavioural, emotional, cognitive, and agentic components and capturing how these dimensions jointly appear through students' actions, feelings, and learning behaviours in context (Bae & DeBusk-Lane, 2019; Söderholm et al., 2023).

In this literature, the terms student engagement, academic engagement, and engagement profiles are often used interchangeably to describe students' active involvement in learning processes (Schmidt et al., 2018; Wong & Liem, 2022). These concepts collectively refer to the extent to which students demonstrate behavioral participation, cognitive investment, emotional commitment, and agentic contribution in meaningful learning activities (Fredricks et al., 2004; Christenson et al., 2012; Reeve, 2013).

2.3.1. Theoretical foundations of student engagement profiles

Student’s engagement is a multidimensional construct and a strong predictor of academic success, encompassing students’ active participation, emotional investment, and cognitive commitment to learning (Fredricks et al., 2004). It operates across behavioral, cognitive, emotional, and agentic dimensions, which dynamically interact to shape persistence, motivation, and achievement. Reeve (2013) and Reeve and Tseng (2011) emphasize that engagement is not merely observable behavior but also reflects students’ self-regulatory processes, highlighting the role of autonomy and agency in sustaining meaningful involvement. These perspectives underscore that fostering engagement requires attending to the interplay of behavioral actions, cognitive effort, emotional investment, and self-directed agency to enhance learning outcomes.

2.3.1.1. Self-Determination Theory (SDT)

Self-Determination Theory explains motivation, engagement, and well-being in educational contexts (Ryan & Deci, 2000). The theory proposes that optimal motivation and learning occur when three basic psychological needs are satisfied, such as autonomy (self-directed action), competence (a sense of mastery), and relatedness (feeling connected to others). These needs function as essential psychological resources that support effective learning and well-being (Ryan & Deci, 2000). Unlike traditional models that emphasize rewards and punishments, the theory distinguishes intrinsic motivation, driven by interest and enjoyment, from forms of extrinsic motivation that vary in the degree to which they are internalized. When the needs for autonomy, competence, and relatedness are supported, students are more likely to internalize external goals and sustain motivation, leading to stronger engagement and improved outcomes.

SDT assumes students possess inherent growth tendencies, such as intrinsic motivation and curiosity, which underpin high-quality classroom engagement (Ryan & Deci, 2000). When students perceive themselves as autonomous, competent, and connected, they exhibit self-determined motivation, leading to increased engagement without reliance on external rewards (Wang & Amemiya, 2019). A strong sense of competence reduces anxiety and enhances students' capacity to tackle challenges, fostering greater engagement (Wigfield & Wagner, 2005). Relatedness, supported by warm and valuing interactions, satisfies the need for belonging, further promoting engagement (Hejazi et al., 2009). Autonomy, by fostering a sense of responsibility for one's actions, enhances performance and engagement by minimizing external control (Reeve, 2013).

Student engagement is conceptualized as an outcome of motivational processes, driven by inner resources and their interaction with classroom conditions (Reeve, 2013). SDT emphasizes that high-quality motivation emerges when students experience autonomy, competence, and relatedness during learning activities. Other motivational frameworks, such as expectancy theory, complement SDT by highlighting how students' expectations, beliefs, and goals shape engagement (Reeve, 2013). SDT underscores the instructional role of nurturing these inner motivational resources to facilitate robust engagement (Reeve & Lee, 2014).

SDT proposes a continuum of motivation, ranging from amotivation (lack of intention to act) to extrinsic motivation (driven by external rewards or internalised values) and finally to intrinsic motivation (driven by interest and enjoyment). Within extrinsic motivation, Deci and Ryan (2000) distinguish between external regulation, introjected regulation, identified regulation, and integrated regulation. As learners internalise external goals, such as understanding the relevance of a task to personal aspirations, they move along this continuum toward more autonomous forms of motivation. This internalisation process is strongly influenced by whether the learning environment satisfies the three basic psychological needs (Ryan & Deci, 2000).

Self-Determination Theory explains that student motivation and engagement are strongly shaped by the learning environment, which can either support or undermine students' psychological needs (Skinner & Pitzer, 2012). Supportive student–teacher interactions, including pedagogical caring that nurtures relatedness, clear structure that develops competence, and autonomy-supportive practices that encourage self-determination, are essential for fostering engagement (Patall et al., 2018; Reeve & Lee, 2014). When the needs for autonomy, competence, and relatedness are fulfilled, students are more likely to develop intrinsic and autonomous motivation, leading to stronger engagement and improved learning outcomes (Ryan & Deci, 2000).

2.3.1.2. Expectancy–value Theory

Originally developed by Atkinson (1957), Expectancy–Value Theory is a widely recognised motivational framework that explains how individuals' beliefs about their ability to succeed and the value they assign to a task influence their engagement, effort, and achievement. In the context of achievement motivation, the theory was significantly refined and extended by Wigfield and Eccles (2000). According to expectancy–value theory, students' motivation and subsequent academic behaviours are shaped primarily by two interrelated components: expectancy for success and subjective task value. These components work together to determine students' decisions to engage in learning activities, the intensity of their effort, and their persistence over time (Wigfield & Eccles, 2000).

The expectancy component refers to a learner's beliefs about how well they will perform on a specific task, both immediately and in the future. It is influenced by previous experiences, self-concept of ability, feedback from significant others, and interpretations of past successes or failures (Eccles & Wigfield, 2002). For example, a student who consistently receives positive feedback in mathematics and has a strong sense of competence is likely to have a high expectancy of success in future mathematics tasks. High expectancy beliefs increase the likelihood that students will invest effort, persist when facing challenges, and adopt adaptive learning strategies.

The value component refers to how much a learner sees a task as worthwhile, interesting, or useful. Wigfield and Eccles (2000) identify four subcomponents of task value. Intrinsic value involves the enjoyment or interest in the task itself. Attainment value reflects the personal importance of doing well, often linked to one's identity or standards. Utility value refers to the perceived usefulness of the task for future goals, such as careers. Cost includes the negative aspects of engagement, such as effort, anxiety, or lost opportunities. Tasks that are high in intrinsic, attainment, or utility value and low in perceived cost are more likely to sustain student engagement (Eccles & Wigfield, 2002).

In educational settings, expectancy–value theory explains differences in students' behavioral, emotional, cognitive, and agentic engagement. Students who have strong expectations for success and place high value on tasks are more likely to participate actively, show positive attitudes, use deeper learning strategies, and act autonomously. In contrast, low expectations or low task value often result in superficial engagement or disengagement. Practices such as supportive feedback, achievable challenges, and a positive classroom environment can strengthen students' expectations, while relevance, meaningful choices, and links to students' interests and goals can enhance task value (Wigfield et al., 2017).

2.3.2. Dimension of engagement profiles

Although there is broad agreement among researchers that student engagement is a multidimensional construct, there remains no single, widely accepted framework defining its exact structure, as different theoretical models propose varying configurations ranging from two to three or four core dimensions of engagement (Alrashidi et al., 2016), highlighting ongoing differences in how its components are conceptualized and organized, as summarized in Table 1.

Table 1

Dimensional variation across engagement models.

Authors	Engagement dimensions
Schaufeli *et al*. (2002)	Vigor, dedication, and absorption
Willms (2003	Behavioral and psychological
Fredricks *et al*. (2004)	Behavioral, emotional, and cognitive
Reschly and Christenson (2012)	Academic, behavioral, psychological, and cognitive
Reeve & Tseng (2011)	Emotional, cognitive, behavioral, and agentic
Finn (1989)	Behavioral and emotional
Audas and Willms (2002)	Behavioral and psychological
Finn and Zimmer (2012)	Academic, affective, social, and cognitive
Jimerson *et al*. (2003)	Affective, behavioral, and cognitive

2.3.2.1. Cognitive engagement

Cognitive engagement refers to the mental effort and strategies students use to understand and process information, a key concept in Educational Psychology (Fredricks et al., 2004). It includes surface processing, such as memorizing information with little understanding, and deep processing, where students connect ideas, think critically, and apply knowledge (Feng & Hong, 2022; Greene et al., 2004). For instance, analyzing causes of a historical event reflects deep processing, while simply recalling dates reflects surface processing. Cognitive engagement is important for academic success because it shows how well students internalize learning, though it may not always be visible in their behavior (Achwani et al., 2025).

2.3.2.2. Behavioural engagement

Behavioural engagement refers to students' observable participation in academic and classroom activities, including active behaviours such as contributing to discussions, asking questions, following instructions, completing assignments, and adhering to classroom rules, as well as avoiding negative behaviours like absenteeism, disruption, or withdrawal (Fredricks et al., 2004, 2016; Goodman, 2016). It reflects the visible ways students interact with the learning environment and serves as an important indicator of their involvement in school activities.

However, although behavioural engagement is essential for learning, it does not fully capture students' deeper cognitive or emotional investment, as students may demonstrate compliance without genuine intellectual or emotional commitment to the task (Lawson & Lawson, 2020).

2.3.2.3. Emotional engagement

Emotional engagement refers to students' affective responses to learning, including interest, enjoyment, and belonging (Fredricks et al., 2004). Positive emotions such as interest and enjoyment support motivation and sustained involvement in learning tasks, often reinforcing attention and persistence (Ainley & Ainley, 2011; Schmidt et al., 2018), whereas negative emotions like boredom or anxiety are linked to disengagement (Blankson et al., 2017). Overall, it influences students' intrinsic motivation and their continued engagement with academic activities over time (Murphy et al., 2019).

2.3.2.4. Agentic engagement

Agentic engagement refers to students' active and proactive involvement in shaping their learning experiences (Reeve & Tseng, 2011). It includes behaviors such as asking questions, seeking clarification, offering suggestions, and taking initiative in learning activities (Reeve, 2013). Motivated by factors such as self-efficacy, agentically engaged students do more than passively follow instruction; they actively contribute to and influence classroom learning. As a complement to behavioural, cognitive, and emotional engagement, agentic engagement has been linked to better skill development, higher academic performance, and improved achievement (Reeve & Tseng, 2011; Reeve, 2013).

Figure 1

Stages of Agentic Engagement (Source. Roy, 2017, p. 42).

Figure 1 shows a three-stage model of engagement in learning. Fredricks et al. (2004) define engagement as behavioural, cognitive, and emotional, but Reeve and Tseng (2011) note these are mostly reactive to teacher instruction. They add agentic engagement, students' proactive actions like asking questions or giving suggestions, to better support learning and achievement (Reeve, 2013). The present study therefore uses a four-dimensional model, behavioural, cognitive, emotional, and agentic, to capture engagement's full role in academic success.

2.3.2.5. The interplay of engagement dimensions

Student engagement works best when its dimensions reinforce each other rather than operate separately (Fredricks et al., 2004; Lawson & Lawson, 2013). Cognitive engagement involves mental effort in understanding and problem-solving, while behavioral engagement refers to actions like participation, persistence, and effort (Goodman, 2016). These two are closely linked: students who think deeply about a task are more likely to stay engaged in doing it, and active participation further strengthens understanding through practice, "doing" supports "thinking," and thinking reinforces doing (Sinatra et al., 2015).

Emotional engagement, including students' interest, enjoyment, and sense of value, directly influences cognitive engagement (Blankson et al., 2017). Positive emotions, such as curiosity about renewable energy solutions, enhance concentration, critical thinking, and problem-solving, while successful cognitive engagement reinforces emotional engagement by fostering accomplishment, satisfaction, and motivation. Emotional and behavioral engagement interact reciprocally in which students who feel supported, competent, or valued are more likely to participate actively, persist in tasks, and complete assignments, and consistent behavioral engagement enhances emotional engagement through increased confidence and reduced anxiety (Li et al., 2024).

Agentic engagement represents students' proactive contribution to the learning process, including asking questions, expressing preferences, and shaping instruction to meet their needs (Reeve, 2013). Agentic engagement interacts with cognitive, behavioral, and emotional dimensions by enabling learners to take ownership of their learning, seek challenges, and sustain motivation. For instance, a student who actively requests clarification on a science experiment (agentic) deepens understanding (cognitive), participates more consistently (behavioral), and experiences greater interest (emotional) (Reeve & Tseng, 2011).

These interactions indicate that engagement is dynamic and mutually reinforcing rather than static. Effective educational interventions should target all four dimensions simultaneously to maximize learning outcomes, as addressing only one dimension may limit the overall impact on student motivation and achievement (Sinatra et al., 2015; Reeve, 2013).

2.3. Empirical Literature Review

This section synthesizes existing empirical evidence on how students perceived linguistic competence, textbook linguistic complexity, and engagement profiles interact to shape science achievement and identifies gaps to guide the present study and reviews key findings, highlighting the integral role of language elements in science education.

2.3.1. Linguistic competence in science education

Empirical research across diverse educational contexts and grade levels consistently demonstrates a positive and significant correlations between linguistic competence, encompassing phonological, lexical, semantic, and syntactic dimensions, and students' comprehension, engagement, and achievement in science (McComas, 2013; Kulgemeyer & Schecker, 2013). While a substantial body of literature examines linguistic competence in broader educational settings (Ardasheva et al., 2021; Neri & Retelsdorf, 2022; Solina, 2022), there is a relative scarcity of studies specifically addressing its multifaceted impact on science outcomes. The available evidence underscores those linguistic skills facilitate the interpretation, construction, and communication of scientific knowledge, thereby enhancing academic performance.

Competence in linguistic features is essential for students to decode questions, comprehend complex arguments, and engage in effective communication with educators and peers (Solina, 2022). Longitudinal and intervention studies illustrate this linkage. For instance, August et al. (2010) reported that inadequate linguistic competence impeded science achievement among middle-grade English language learners, yet targeted interventions focusing on academic vocabulary and science-specific language functions yielded significant improvements. Similarly, Shanahan (2014) found that early oral language skills predicted subsequent success in reading comprehension and content-area learning, including science and mathematics. Snow et al. (2007) further evidenced that explicit academic vocabulary instruction accounted for 22–31% of variance in science outcomes, emphasizing the value of linguistic supports for students facing language barriers.

Over the past two decades, research has consistently linked general and science-specific linguistic skills to comprehension, reasoning, and achievement (Uccelli et al., 2015; Ardasheva et al., 2021; Neri & Retelsdorf, 2022). In the U.S., Guglielmi (2012) used longitudinal latent growth modeling with Grades 8–12 students, finding that initial linguistic competence strongly predicted baseline science achievement ($\beta = .54$, $p < .001$), independent of socioeconomic status and prior performance. Likewise, Wellington and Osborne (2001) showed that secondary students' science success closely depends on their use of precise, contextually appropriate scientific vocabulary, underscoring the link between lexical skill and conceptual understanding.

Historical syntheses reinforce these empirical insights. Yore et al. (2003) reviewed 25 years of research on the literacy-science nexus, evolving from reading-to-learn paradigms to integrated disciplinary literacy models, where language proficiency enables scientific reasoning, description, and argumentation. Lee (2005) synthesized studies on English language learners, concluding that constrained language proficiency limits conceptual acquisition, while dual-focus pedagogies, integrating language and content objectives, enhance both domains. These perspectives advocate embedding literacy instruction within science curricula, particularly in linguistically diverse settings transitioning to abstract discourse.

The reviewed studies converge on the conclusion that linguistic competence is inseparable from science learning and achievement (Phillips Galloway et al., 2020). Textual features such as syntactic density and lexical load interact with learner-level linguistic skills, underscoring the necessity of instruction that addresses both the linguistic demands of scientific texts and the resources students bring to them (Hackemann et al., 2022; Neri & Retelsdorf, 2022). For middle school learners, explicit instruction in academic language, cohesive devices, and technical vocabulary is particularly vital as students transition from everyday speech to abstract scientific discourse (Tytler et al., 2008). Moreover, cultivating students perceived linguistic competence can enhance their engagement, persistence, and long-term science achievement (Hu et al., 2022; Guglielmi, 2012).

Nevertheless, the relationship between linguistic competence and science achievement is not uniformly linear. Owu-Ewie (2012) found that even proficient students may struggle with texts of high lexical complexity, while Neri et al. (2025) showed that the predictive strength of linguistic self-concept and reading comprehension depends on task type and linguistic demand. This suggests that language's impact on science learning is mediated by factors such as text design, teaching methods, and learner background. Language functions not just as a medium for knowledge but as a key cognitive and epistemic tool in constructing scientific understanding (Goldman & Snow, 2015; Young, 2005). Differences across studies likely stem from variations in linguistic measures, instructional language, and the specific demands of science curricula (McComas, 2013; Mönch & Markic, 2022).

Science texts, discourse, and assessments demand strong phonological, lexical, and semantic skills for effective student engagement (Snow, 2010). These competencies help middle schoolers decode, understand, and communicate complex scientific concepts (Quinn et al., 2012). Phonological skills aid accurate pronunciation and term retention, lexical knowledge supports technical vocabulary and complex structures, semantic competence underpins conceptual reasoning, and oral proficiency enhances classroom interaction (Nittrouer et al., 2018). This review synthesizes evidence on how these linguistic dimensions contribute to science achievement.

2.3.1.1. Phonological linguistic competence

Research on language factors in science learning has largely focused on vocabulary and general language proficiency, while phonological linguistic competence has received limited attention. Phonological competence refers to knowledge of a language's sound system, including the ability to pronounce, recognize and manipulate words, a concept rooted in the broader theory of linguistic competence proposed by Chomsky (1965, 1968). Although phonological skills are known to support early reading development, empirical evidence linking phonological competence directly to achievement in science is scarce.

Most studies instead emphasize lexical knowledge and disciplinary literacy, indicating that the role of phonological competence in science achievement remains insufficiently explored in the literature. Research has predominantly focused on written language, neglecting that oral and phonological competencies are equally vital for effective science learning. Empirical research consistently identifies phonological competence as a foundational component of literacy and, by extension, science learning. Phonological awareness, comprising the ability to recognize, manipulate, and produce sound patterns, enables accurate decoding of scientific vocabulary, pronunciation of technical terms, and comprehension of written texts (Novianti & Syihabuddin, 2021).

de Jong and van der Leij (2002) demonstrated through longitudinal analysis that individual differences in phonological processing, combined with linguistic comprehension, significantly predict children's reading development trajectories. Their findings indicate that phonological skills support early decoding, while broader linguistic comprehension underpins later fluency and understanding. Similarly, Melby-Lervåg et al (2012), in a meta-analysis of cross-linguistic studies, confirmed phonological awareness as a strong causal predictor of reading acquisition, establishing its importance for decoding and word recognition.

Further evidence highlights the interdependence between phonological processing and cognitive factors such as working memory. Phonological representations support encoding and retrieval processes in learning contexts, suggesting that phonological competence underlies not only reading but also numerical and verbal reasoning tasks central to science learning (Passolunghi et al., 2007). In second-language (L2) contexts, accurate pronunciation and decoding of scientific terminology are vital for oral participation and comprehension.

Woore (2018) and Darcy (2018) both found that pronunciation errors often reveal decoding difficulties, and that explicit phonological instruction enhances learners' ability to access meaning and engage in scientific discourse. Moreover, Hayes et al. (2006) demonstrated that children's use of vowel and consonant cues in spelling reflects the interaction between phonological and orthographic knowledge, providing evidence that phonological precision facilitates the encoding of scientific vocabulary. These empirical evidences establish phonological competence as the gateway to reading fluency, precise pronunciation, and comprehension of complex scientific language.

2.3.1.2. Lexical linguistic competence

Lexical competence, or mastery of vocabulary, is a strong predictor of success in science learning within Science Education. It includes both vocabulary breadth, the number of words known, and depth, the understanding of meanings and relationships between words.

Research shows that both aspects significantly support reading comprehension, enabling students to better understand scientific texts (Qian, 2002). Studies also highlight that science materials often contain complex language, such as technical terms and abstract concepts, which place high demands on students' vocabulary knowledge (Fang, 2006). Without sufficient lexical competence, learners face difficulty in constructing meaning from these texts (Rupley & Slough, 2010).

Nation (2022) and Cohen (2012) emphasize that explicit vocabulary instruction, particularly focused on technical and academic words, enhances comprehension and content learning in science. Chung and Nation (2004) quantified that approximately one-third of the words in science textbooks are technical in nature, recommending deliberate teaching of such terms to aid conceptual understanding. Uccelli et al. (2015) expanded this view by examining cross-disciplinary academic language proficiency, showing that advanced lexical and syntactic knowledge correlates with improved reading comprehension.

Snow and Uccelli (2009) further argued that lexical competence supports scientific reasoning, argumentation, and written expression, all key components of inquiry-based science education. Students acquire new word meanings more effectively through exposure to authentic texts and contextual inference. Alimbetova (2024) confirmed that using authentic scientific texts enhances vocabulary learning, helping learners develop deeper, transferable lexical knowledge. Moreover, direct discussion, repetition, and linking of vocabulary to hands-on experiences result in durable science vocabulary acquisition (Best et al., 2006).

Llinares et al. (2012) further found that language-integrated approaches such as Content and Language Integrated Learning (CLIL) promote both conceptual and lexical development, especially among multilingual learners. August et al (2009) similarly highlighted that English language learners benefit significantly from explicit teaching of academic and technical vocabulary in science contexts. These studies converge on the conclusion that lexical competence, encompassing both academic and technical vocabulary, is essential for scientific literacy, conceptual understanding, and effective communication in middle school science classrooms (Gonzalez, 2013; Hu et al., 2021).

2.3.1.3. Semantic linguistic competence

Semantic competence refers to the ability to understand and manipulate meanings and conceptual relationships within language (Johnson & Lepore, 2004). Empirical evidence on semantic linguistic competence in science education remains relatively limited, despite growing recognition of its centrality to disciplinary learning. The few available studies, however, consistently indicate that students' ability to comprehend and use the semantic linguistic feature of scientific language strongly influences their conceptual understanding. For example, Hamnell-Pamment (2024) observed that chemistry students with higher semantic precision in their written explanations produced more coherent and conceptually integrated concept maps, reflecting deeper understanding of scientific phenomena.

In science education, semantic competence involves linking words to concepts, interpreting relationships between scientific terms, and constructing coherent explanations (Soames, 2022). Empirical studies demonstrate that semantic competence directly supports comprehension and reasoning in science learning. Yun (2020) found that students with well-structured semantic networks, mental representations of interconnected scientific concepts, displayed superior conceptual understanding.

Meidell Sigsgaard (2025) emphasized that engaging students in language activities that move between abstract and concrete meanings, described as "semantic waves," enhances their capacity to connect scientific theory to real-world contexts. Semantic understanding is also crucial for interpreting scientific models, analogies, and symbolic representations (Haglund, 2012). Adúriz-Bravo (2020) and Haglund (2012) found that successful reasoning with models in topics such as thermodynamics or biology depends on learners' recognition of semantic relationships among terms and variables.

Classroom discourse analysis by Mortimer and Scott (2003) revealed that semantic competence underpins students' ability to interpret teacher explanations, construct meaning collaboratively, and express scientific reasoning coherently. Similarly, Pagaard, eta al. (2023) demonstrated that when teachers explicitly guide students in semantic reasoning, by connecting terminology, diagrams, and real phenomena, students show improved conceptual understanding and communication. Further, a systematic review of 35 empirical studies on teachers' pedagogical scientific language knowledge found that many educators lacked awareness of the distinct semantic and syntactic features of scientific registers, such as nominalisation and passive constructions, which limited their ability to scaffold students' linguistic development in science (Mönch & Markic, 2022).

Although these findings collectively underscore a clear connection between linguistic competence and science learning, the research base remains narrow; most studies are small-scale, qualitative, or correlational, and there is a notable scarcity of longitudinal or experimental work directly examining how developing semantic linguistic competence influences students' conceptual change in science. Consequently, this area represents a critical yet underexplored frontier for future empirical inquiry in science education research. Taber (2009) underscored that failure to develop semantic understanding leads to persistent misconceptions, particularly in chemistry and physics.

2.3.2. Linguistic complexity and lexical density in educational reading texts

Research across disciplines shows that educational texts often have high lexical density, exceeding learners' linguistic capacity. Maufiroh et al. (2024) found that English passages in secondary textbooks can hinder comprehension for EFL students. Similarly, Gül (2021) reported that Turkish middle school biology texts often exceed students' reading levels.

Strohmaier et al. (2023) confirmed in a STEM meta-analysis that lexical sophistication and morphological complexity consistently predict comprehension performance. These findings indicate that high lexical density, common in academic language, can reduce accessibility without explicit linguistic support.

Beyond vocabulary, syntactic structure significantly influences comprehension. Arya et al. (2011) demonstrated that texts containing longer noun phrases, passive constructions, and embedded clauses impede elementary learners' understanding of science concepts. This finding was corroborated by Lodge (2021), who, through qualitative inquiry, reported that teachers frequently described science texts as "complex and confusing," primarily due to their syntactic density and clause chaining. More recent computational research by Nadeem and Ostendorf (2018) advanced the methodological sophistication of the field by developing natural language processing (NLP) tools to estimate linguistic complexity across large text corpora. Their study confirmed that computational indices of syntactic depth correlate strongly with traditional human readability assessments.

A growing body of research emphasizes that linguistic complexity is not uniform across school subjects but instead reflects discipline-specific conventions. Neri et al. (2025) analyzed expository texts from German STEM textbooks and identified distinct linguistic feature patterns across disciplines; mathematics texts relied on symbolic and condensed expressions, while biology and physics texts employed nominalized expository prose. This confirms that each subject "has its own language," requiring tailored linguistic analysis. Complementing this perspective, Özalp (2023) examined Turkish science textbooks and found a disconnect between curriculum goals, which emphasized inquiry and science process skills, and the linguistic realization of those skills within textbook tasks. This misalignment suggests that linguistic features in textbooks do not always support the development of intended cognitive and procedural competencies.

Despite the considerable progress in analysing the linguistic complexity of textbooks, several limitations continue to constrain the existing evidence base. Methodological inconsistency remains a central challenge, as studies employ diverse and often incomparable metrics of complexity, ranging from T-unit length and type–token ratios to computational indices, thereby hindering cumulative interpretation across research contexts based on learners' perception (Strohmaier et al., 2023). Much of the current literature is confined to Western or EFL educational settings, which restricts the generalizability of findings to broader linguistic and cultural environments (Maufiroh et al., 2024; Gül, 2021). Another persistent limitation lies in the narrow linguistic scope of many analyses, which tend to prioritize lexical and syntactic dimensions while overlooking other critical aspects of language.

Although psycholinguistic research has long established that phonological decoding and semantic integration are central to reading fluency and conceptual understanding (Nation, 2019; Perfetti & Stafura, 2014), these dimensions are rarely examined in the context of students' engagement and science achievement, where the focus tends to remain on vocabulary load and sentence complexity. Taken together, these gaps underscore the need for an integrative research framework that bridges linguistic, cognitive, and educational perspectives. Future research should therefore incorporate psycholinguistic methods to explore how phonological, lexical, and semantic features collectively affect learners' engagement, comprehension, and achievement in science.

2.3.3. Textbook linguistic complexity, academic engagement, and science achievement

Research on the linguistic demands of science textbooks and instructional materials highlights the central role of language in shaping students' engagement and achievement in science learning. Textbooks, as primary mediators of disciplinary knowledge, vary widely in linguistic complexity across disciplines, grade levels, and instructional contexts. Green (2019) employed natural language processing (NLP) techniques to provide a multilevel analysis of textbook linguistic features, revealing that increased lexical density and syntactic complexity in textbooks create heightened comprehension demands for students, particularly in science.

Similarly, Berendes et al. (2018) examined secondary school textbooks and found that linguistic complexity systematically rises with grade level and is higher in academically oriented school tracks, underscoring that students' reading proficiency must keep pace with escalating textual demands to maintain comprehension and engagement. These findings align with Lodge's (2021) qualitative analysis, which identified that secondary science texts are often "complex and confusing," with dense syntax and technical vocabulary that can hinder students' meaning-making and conceptual integration.

Other studies have emphasized the implications of linguistic complexity for learning outcomes and instructional design. Eltinge and Roberts (1993) introduced linguistic content analysis as a method to quantify how textbooks present science as inquiry, revealing that the interplay of syntactic structure, lexical choice, and discourse organization significantly influences students' engagement with scientific reasoning. Hu and Gao (2018) extended these findings in the Hong Kong context, showing that English-language science textbooks present considerable linguistic challenges for non-native speakers, particularly through discipline-specific terminology and multi-clausal sentence structures.

Interactional pattern in linguistically diverse classrooms influence students' participation and conceptual understanding, emphasizing that teacher mediation and scaffolded language support can mitigate comprehension barriers (Lee & Fradd, 1996). Namaziandoost et al. (2024) highlighted the importance of vocabulary learning in fostering academic engagement among students, showing that lexical proficiency predicts both willingness to communicate and engagement with science texts. Similarly, multimodal textbook approaches, which integrate diagrams, text, and interactive representations, have been shown to improve scientific literacy by providing alternative pathways to conceptual understanding (Zakiya et al., 2017).

Language literacy interventions, including targeted vocabulary instruction and structured engagement with text, are essential for promoting both comprehension and achievement in science, particularly for learners encountering high linguistic demands (Moeed & Cooney, 2021). Studies further indicate that the linguistic features of instructional materials can significantly influence how students engage with content and, consequently, their academic performance in science.

Strohmaier et al. (2023) synthesized 45 experimental studies examining the impact of linguistic modifications in STEM texts on student comprehension and engagement. They found that texts with moderate to high lexical density and syntactic complexity elicited greater cognitive engagement, such as increased time spent analyzing relationships and integrating ideas, and higher self-reported effort; however, achievement gains were modest and varied depending on students' prior ability levels. Moschitti and Basili (2004) similarly emphasized that overly complex texts can hinder understanding, whereas appropriately challenging materials promote engagement, vocabulary development, and self-regulatory practices. Furthermore, Hamnell-Pamment (2024) demonstrated that students' use of scientific language and their ability to structure sensemaking tasks were positively correlated with achievement levels in chemistry.

These empirical evidences underline that linguistic complexity in science textbooks is not merely a peripheral issue but a core determinant of students' comprehension, engagement, and achievement (Berendes et al., 2018; Lodge, 2021). Effective science education requires attention to the alignment between students' linguistic competence and the demands of instructional materials, including lexical, syntactic, and discourse-level features. For middle and secondary school students, especially those learning science in a second language, integrating language-focused scaffolding, vocabulary support, and multimodal representations within science instruction can enhance understanding, engagement, and overall achievement (Green, 2019; Namaziandoost et al., 2024; Moeed & Cooney, 2021).

2.4. Student engagement in middle school science achievement

Empirical research over the past decade emphasises the pivotal role of students' engagement, conceptualized multidimensionally as behavioural (e.g., participation and effort), emotional (e.g., interest and enthusiasm), cognitive (e.g., strategic learning and self-regulation), and agentic (e.g., proactive contributions), in predicting middle school students' science achievement (Fredricks et al., 2004; Reeve & Lee, 2014; Reeve 2013). This body of evidence, drawn from longitudinal studies, meta-analyses, and mixed-methods profiles, reveals consistent positive correlations between higher engagement levels and improved science outcomes, including test scores, conceptual understanding, and persistence in inquiry-based tasks (Achwani et al., 2025; Cairns & Areepattamannil, 2019; Grabau & Ma, 2017).

Engagement profiles vary with student demographics, school context, and instructional practices, affecting interventions to counter declines during middle school (Benner & Wang, 2014; Grabau & Ma, 2017; Skinner et al., 2016; Wang & Amemiya, 2019). Person-centered studies reveal diverse engagement patterns with different effects on science achievement. Söderholm et al. (2023) found that students often shift from higher to lower engagement over time, increasing the proportion of low-engaged learners. Those perceiving stronger academic and social support were more likely to maintain high engagement, highlighting the importance of supportive learning environments in upper secondary education.

Research using person-centered analyses indicates that students' engagement profiles are significantly associated with science achievement. For instance, a latent profile analysis conducted by Bae and M. DeBusk-Lane (2019) found that students classified in moderately engaged and behaviorally engaged profiles demonstrated higher science achievement, whereas students in disengaged profiles showed comparatively lower performance. These findings suggest that higher levels of cognitive, behavioral, and affective engagement are positively related to students' academic outcomes in science. Similarly, Wang and Peck (2013) found that adolescents' school engagement profiles were significantly associated with both educational outcomes and mental health, with highly engaged students exhibiting higher academic achievement and better psychological well-being than less engaged peers.

Sedigo et al. (2015) found that cognitive engagement was positively correlated with science performance ($r = 0.249$, $p < 0.001$), behavioral engagement showed a smaller positive correlation ($r = 0.170$, $p = 0.016$), and affective engagement was not significant ($r = 0.070$, $p = 0.327$), indicating that cognitive involvement most strongly predicts students' science performance. Wang and Eccles (2013), in a longitudinal investigation of 1,057 U.S. adolescents transitioning to middle school, used structural equation modeling to demonstrate bidirectional effects: initial emotional and cognitive engagement predicted 12% variance in subsequent science grades ($\beta = 0.31$, $p < .001$), mediated by achievement motivation and school belonging, with effects strongest for underrepresented minorities.

Lee et al. (2016) found that intrinsic motivation strongly predicted engagement ($\beta \approx 0.93$, $p < .001$), which in turn positively influenced middle school science achievement ($\beta \approx 0.45$, $p < .05$), with engagement partially mediating the effect of intrinsic motivation on performance, while extrinsic motivation showed no significant effects. Lei, Cui, and Zhou's (2018) meta-analysis of 69 independent studies (196,473 participants) found moderately positive correlations between student engagement and academic achievement, with overall engagement correlating at $r = .269$ ($p < .001$), behavioral engagement at $r = .350$ ($p < .001$), emotional engagement at $r = .216$ ($p < .001$), and cognitive engagement at $r = .245$ ($p < .001$), demonstrating that higher levels of each engagement domain are associated with higher academic achievement across diverse contexts.

Lei, et al. (2018) meta-analysis of 69 independent studies (total $N \approx 196{,}000$) found moderately positive relationships between student engagement and academic achievement across multiple engagement dimensions: overall engagement was correlated with achievement at $r = 0.269$ ($p < .001$), behavioral engagement at $r = 0.350$ ($p < .001$), emotional engagement at $r = 0.216$ ($p < .001$), and cognitive engagement at $r = 0.245$ ($p < .001$), indicating that higher levels of engagement are consistently associated with higher academic performance across diverse contexts.

Additionally, Symonds et al. (2026) conducted a large meta-analysis of 125 longitudinal studies with repeated measures of student engagement among adolescents aged 10–18 and found that engagement across behavioural, emotional, cognitive, and academic dimensions showed a small but statistically significant overall decline across adolescence ($\Delta = -0.09$, $p < 0.001$); the decline was most pronounced in early adolescence and during school transitions, and this pattern was consistent regardless of gender, type of engagement, or study publication date.

Hu et al. (2022) developed a mixed-methods instrument focusing on perceived competence and found it was a strong predictor of high school students' science self-efficacy ($r = .62$, $p < .001$), with both competence and self-efficacy increasing over time. Li, He, and Peng (2024) reported that high school science engagement is multidimensional—cognitive, emotional, behavioral, and agentic, and that all subscales positively correlated with achievement, with cognitive, behavioral, and agentic engagement showing the strongest links, emphasizing the role of students' initiative alongside effort and attention in learning.

Mediation studies highlight engagement's key role. Research in middle school contexts indicates that competence beliefs, such as self-efficacy, positively predict student engagement, which in turn enhances academic achievement. For example, Bae and DeBusk-Lane (2019) found that students with higher self-efficacy were more likely to belong to moderately or highly engaged science learning profiles, which were associated with higher achievement. Similarly, Lee et al. (2016) reported that intrinsic motivation and competence beliefs significantly increased engagement, which then predicted science performance, confirming that engagement mediates the relationship between perceived competence and academic outcomes.

2.5. Perceived linguistic competence, textbook linguistic complexity, engagement profiles, and science achievement

Perceived linguistic competence, defined as students' self-assessed ability to effectively utilize phonological, lexical, and semantic language elements for communication, comprehension, and expression, is a pivotal factor in science education, often conceptualized as language self-efficacy (Bandura, 1997). This construct significantly influences motivation, persistence, and academic performance, particularly in multilingual contexts where language mediates scientific understanding, argumentation, and engagement. Though limited, empirical evidence examining the link between linguistic-related factors and students' engagement profiles in science learning remains mixed.

Beyond measurable linguistic abilities, students' self-perceptions of their linguistic competence significantly influence engagement and achievement in science. Hu et al. (2022) developed and validated a science self-efficacy scale centered on perceived language competence, demonstrating that students' confidence in navigating scientific language predicted higher engagement and improved learning outcomes. Neri and Retelsdorf (2022) similarly emphasized that reliable assessment of linguistic constructs is essential for understanding how language proficiency mediates science performance. Together, these findings introduce an affective dimension to linguistic competence: students who believe they can successfully use scientific language are more motivated to participate and persist in science learning activities.

Strohmaier et al. (2023) examined how variations in STEM texts' linguistic features, including lexical density, syntactic complexity, and cohesion, affected student comprehension and engagement. They found that texts with moderate to high lexical and syntactic complexity elicited greater cognitive engagement, such as deeper relational thinking and idea integration, as well as higher self-reported effort; however, gains in achievement were modest and depended on students' prior ability. Similarly, Rhodes et al. (2020) found that using action-focused language ("do science") instead of identity-focused language ("be scientists") increased young children's engagement and persistence in science tasks, demonstrating that subtle linguistic cues can significantly influence early science participation.

Although these studies did not always measure linguistic complexity explicitly, they highlight that students' engagement profiles are sensitive to the language demands of science instruction, underscoring the importance of aligning text complexity with learners' linguistic competence. Schunk and DiBenedetto (2021) explain that self-efficacy is a central motivational belief that influences students' choices, persistence, effort, and resilience in learning contexts, and they summarize extensive evidence showing that higher self-efficacy is consistently associated with better academic performance because it enhances students' engagement, strategy use, and goal commitment across diverse educational domains, thereby positioning self-efficacy as a key driver of motivated behavior and achievement. Zhu et al. (2022) reported that perceived linguistic competence positively influenced motivational engagement ($\beta = 0.29$, $p < .01$) and indirectly improved science achievement through increased cognitive persistence.

Similarly, Wellington and Osborne (2001) observed that students learning science in a non-native language displayed lower engagement and conceptual understanding, attributing disengagement to insufficient mastery of scientific linguistic features. Together, these findings indicate that students' perceived linguistic competence and the linguistic complexity of instructional materials jointly shape emotional engagement and persistence, highlighting language proficiency as a critical determinant of equitable science learning outcomes.

Perceived linguistic competence drives students' willingness to tackle challenging tasks, invest effort, and persevere, as articulated by self-efficacy theory (Bandura, 1997; Hao & Lu, 2024). In science education, confidence in phonological, lexical, and semantic skills enables students to decode complex terminology, comprehend explanations, engage in discussions, and employ effective learning strategies. Snow (2010) found that such confidence fosters positive academic identities and enhances performance by facilitating navigation of the linguistic demands of science curricula, including textbooks and classroom discourse.

Students with high language self-efficacy are more likely to enrol in advanced science courses, actively participate in inquiry-based learning, and persist in problem-solving, with interventions targeting vocabulary development, morphological analysis, and concept mapping enhancing both competence and motivation (Bandura, 1997; Hu et al., 2022; Wigfield & Eccles, 2000). This confidence shapes effective interactions with science texts, lectures, and discussions, fostering comprehension and participation, as language is central to scientific meaning-making (Lemke, 1990; Sutherland & Dennick, 2002; Hackemann et al., 2022). Addressing perceived competence is crucial for equitable learning, mitigating misjudgments based on linguistic form, and promoting sustained STEM engagement (McComas, 2013; Van Staden, 2022).

Engagement usually depends on an individual's self-perceptions of actual achievements and perceived competence (Schunk & DiBenedetto, 2021). These two perceptions are purported to act as precursors of self-efficacy, predictors of sustained and effortful engagement within an activity (Bandura, 1993, 1997). Such engagement involves the expenditure and sustaining of effort optimally catalyzed when the causes of competence are controllable. Such perceptions of competence are constantly evolving and are usually informed by factors such as relevancy and readability of materials, feedback from teachers, personal aspirations, intrinsically motivated goals, self-endorsed values, and a self-determined approach to activities through perceived autonomy-orientated causation that are informed and internalized through context-specific experiences and self-perceptions (Reeve, 2013).

Chall and Dale (1995) reported that overly simplified instructional language reduced students' motivation and participation, whereas moderate linguistic complexity fostered deeper comprehension and sustained engagement. Similarly, August et al. (2009) observed that students exposed to complex linguistic features demonstrated greater active engagement, analyzing, evaluating, and synthesizing scientific information more effectively. Empirical evidence from linguistic analyses of STEM texts (Strohmaier et al., 2023) further demonstrates that textual clarity, lexical sophistication, and semantic cohesion modestly but significantly affect comprehension and learning, particularly among students with limited prior knowledge (Wu et al., 2021).

Despite growing evidence on engagement and language in science learning, several empirical gaps persist. Existing research commonly aggregates middle-school grades, overlooking grade-specific transitions such as seventh grade, when linguistic and conceptual demands intensify (Aker & Ellis, 2019). Few studies concurrently examine students' perceived linguistic competence and textbook linguistic complexity as joint predictors of science achievement mediated by engagement; most address these factors separately (Strohmaier et al., 2023). Consequently, the present study focused on seventh-grade science and integrates perceived linguistic competence, objectively assessed textbook complexity, and multidimensional engagement within a structural equation model to address these gaps systematically.

2.6. Engagement Profiles as Mediators

While research emphasizes the role of engagement in general academic performance, there is a lack of empirical evidence exploring its mediating role in the relationship between perceived linguistic competence, textbook linguistic complexity, and science achievement in Ethiopian middle school context. Understanding this pathway is key for designing interventions to improve science learning. While direct mediation studies in science are limited, evidence from other contexts shows engagement's importance. Feng et al. (2022) found that academic engagement mediated the link between achievement emotions and language outcomes, and Tan et al. (2025) showed it fully mediated the effect of intrinsic motivation on learning in metaverse-based language instruction, highlighting engagement as a critical process variable in academic success.

Learners' linguistic competence, or their self-perceptions of language ability, appears to influence how actively they engage in learning tasks. In a study using structural equation modeling, Zhu et al. (2022) found that linguistic competence directly predicted writing achievement and the "ideal self," and that the ideal self was significantly related to multiple types of engagement. Behavioural engagement, in particular, uniquely mediated the relationship between linguistic competence and achievement (Bråten et al., 2022). Similarly, empirical research in other second-language contexts shows that engagement mediates the relationship between affective constructs and language outcomes. For instance, Wang (2023), in a study of Chinese non-English-major students, demonstrated that academic engagement fully mediated the link between second-language grit and English proficiency.

Linguistic features influence engagement, which in turn affects science achievement. Strohmaier et al. (2023) found that moderate to high lexical and syntactic complexity in STEM texts increased cognitive engagement and effort, suggesting engagement mediates the impact of linguistic challenge on learning. Similarly, Rhodes et al. (2020) showed that higher language demands in tasks promoted deeper behavioral and cognitive engagement, supporting comprehension, retention, and application of scientific concepts. These findings indicate that students' ability to navigate complex science texts, through prior competence or instructional support, enhances engagement, which then drives higher science achievement, positioning engagement as a key mechanism linking text complexity and linguistic competence to learning outcomes.

From this evidence, it can be inferred that higher linguistic competence (actual or perceived) may lead to greater behavioural, cognitive, and emotional engagement, as learners with stronger linguistic resources feel more capable, confident, and motivated to invest effort, especially when learning involves language-rich scientific texts or terminology (Fernández et al., 2025; Hackemann et al., 2022; JURKOVIČ, 2010; Zhu et al., 2023). This indicates that engagement can function as a psychological bridge between learner attributes (such as competence) and achievement outcomes. Given the overlapping linguistic and cognitive demands of language and science learning, it is reasonable to hypothesize that a similar mediation mechanism operates in science education in which students with higher linguistic competence (or confidence in their language abilities) engage more actively and, through this engagement profiles, achieve better science outcomes.

2.7. Perceived linguistic competence, textbook linguistic complexity, engagement profiles, and science achievement in Ethiopian contexts

Although studies exist on language learning, literacy, and academic engagement, empirical evidence in Ethiopia is scarce on how perceived linguistic competence, textbook linguistic complexity, and academic engagement jointly affect science achievement. In Ethiopia, English is the dominant medium of instruction for science education, despite the country's linguistic diversity (Seid, 2016). This poses significant challenges, particularly in subjects like science, which require advanced language proficiency, conceptual understanding, and reasoning skills (Taye & Teshome, 2025).

Research on the role of language in education in Ethiopia consistently underscores the impact of mother-tongue instruction on student learning outcomes. Nekatibeb (2007) conducted a case study with Grade 8 students and demonstrated that learners instructed in their first language achieved higher academic performance, with scores averaging 42.30% compared to 36.23% for those taught in an English language, and language of instruction accounted for 37.3% of variance in achievement. This finding aligns with broader educational theory suggesting that instruction in a familiar language reduces cognitive load and enhances comprehension, retention, and conceptual understanding (Arega, 2024; Eshetie et al., 2025).

Heugh, et al. (2007), in a government-commissioned study on primary school instruction, similarly reported that prolonged mother-tongue instruction leads to higher scores across subjects, with up to an 11% advantage in subjects like mathematics, biology, and English. Ramachandran (2012), using data from a natural experiment following Ethiopia's 1994 language policy reform, found that mother-tongue instruction increased the likelihood of completing six or more years of schooling, indicating that linguistic related factors not only affect immediate academic performance but also long-term educational attainment. Prinsloo et al. (2018), in the South African context, reinforced these findings by noting that language proficiency relative to the instructional medium affects achievement in science, a pattern consistent with multilingual education literature.

Other studies extend the analysis to materials and classroom practices. While Taye (2025), Alemneh & Mengistie (2023), and Hunegnaw and Melesse (2023) could not be independently verified, their research topics, ranging from literary text integration in Grade 7 to 12 English to reading skills development and science process skill evaluation, reflect the broader consensus that text complexity, task design, and alignment with learners' linguistic and cognitive levels are critical for achievement. James (2018) also likely examines language and learning relationships in Ethiopia, though the dissertation could not be verified, and Geremew and János (2025) purportedly offer a systematic review on language of instruction and cultural inclusion, but the study could not be accessed for empirical confirmation.

Textbook complexity is another key determinant of science learning. Ethiopian science textbooks often feature dense terminology and complex syntax, which can challenge students with limited language proficiency (Taye & Teshome, 2025) and reduce engagement and comprehension (Moges, 2025). However, few studies examine how textbook complexity interacts with students' perceived linguistic competence to influence engagement and achievement. Understanding this relationship is essential for creating linguistically responsive, engagement-focused instructional materials that support diverse learners and improve science outcomes in Ethiopian classrooms.

2.8. Identified Gaps in the Literature

Research on science education in Ethiopia recognizes the importance of language in learning, yet significant gaps remain in understanding how students' linguistic competence and the linguistic complexity of textbooks affect science achievement. Science learning requires comprehension of specialized vocabulary, complex sentence structures, and abstract explanations typical of scientific discourse. When instructional materials exceed students' language abilities, comprehension difficulties may arise, limiting conceptual understanding and academic performance. Although previous studies in Ethiopia have examined English language learning, motivation, and language learning strategies, they mainly focus on language acquisition rather than its role in supporting subject learning. Consequently, empirical evidence on how students' linguistic competence interacts with science learning, particularly in middle school contexts where academic texts become more complex, remains limited.

Another important gap concerns the linguistic complexity of science textbooks used in Ethiopian schools. Textbooks serve as the main instructional resource in many classrooms, and students rely heavily on them to understand scientific concepts and complete learning tasks. However, few studies have systematically examined the linguistic features of these textbooks, such as vocabulary difficulty, sentence structure, and conceptual density. Without such analysis, it is difficult to determine whether the language level of textbooks matches students' linguistic abilities. A mismatch between textbook language and students' language proficiency may hinder comprehension, reduce learning efficiency, and negatively affect science achievement. Therefore, examining the linguistic characteristics of science textbooks and their alignment with students' language competence remains an important research need.

The other gap concerns the limited attention given to how language-related factors influence students' engagement in science learning. Student engagement is widely viewed as a multidimensional construct that includes cognitive, behavioral, emotional, and agentic components. Although previous studies show that engagement is closely related to academic achievement, little research has examined how students' linguistic competence and the linguistic complexity of textbooks shape these engagement dimensions. When students struggle to understand the language used in instruction or textbooks, they may experience frustration, reduced participation, and fewer opportunities to contribute actively in class, which can weaken their overall engagement with science learning.

Most existing research in Ethiopian educational contexts examines direct relationships between variables such as motivation, engagement, or language proficiency and academic performance. Few studies investigate the mechanisms through which these factors interact. In particular, the mediating role of engagement profiles in linking linguistic competence and textbook linguistic complexity with science achievement has not been sufficiently explored. Understanding these mediational pathways is essential because language factors may influence learning outcomes indirectly by shaping how students engage cognitively, behaviorally, emotionally, and agentically with scientific content. Without examining these mechanisms, it is difficult to develop comprehensive models explaining how language influences science learning in classroom contexts.

Another important gap is that most studies in Ethiopia have focused on secondary schools and higher education, with limited attention given to middle school students. Middle school is a critical transition period when learners face more complex academic language, abstract scientific concepts, and increased use of English as the medium of instruction. Difficulties in understanding scientific texts at this stage can affect students' future learning and science achievement. Therefore, research on middle school students is essential to identify early challenges and support long-term academic success.

Addressing these research gaps is important for several reasons. First, it helps identify language-related barriers that hinder effective science learning and improve instructional practices. Second, evidence on the linguistic complexity of science textbooks can guide curriculum developers in designing materials that align with students' language abilities. Third, examining engagement profiles as mediating factors can support teaching strategies that enhance students' participation and learning. Finally, addressing these gaps can provide a clearer understanding of how language, engagement, and science achievement interact in Ethiopian middle school education.

2.9. Conceptual Frameworks of the Study

Science learning in middle school is influenced not only by students' cognitive abilities but also by the linguistic demands of instructional materials and their perceived linguistic competence. For seventh-grade students, science textbooks are a key source of disciplinary knowledge; however, their dense language, abstract concepts, and academic structure can challenge learners who are still developing proficiency in academic language. Students' beliefs about their linguistic competence and their perceptions of textbook difficulty shape their engagement with science tasks and, consequently, their academic achievement. To examine these influences, the present study draws on two complementary conceptual frameworks.

The first conceptual framework conceptualizes textbook linguistic complexity as an inherent property of instructional materials. It treats complexity as a multidimensional construct encompassing lexical, semantic, and discourse-level features that shape processing demands. Drawing on systemic functional and computational linguistics, it characterizes science textbooks as disciplinary texts marked by dense vocabulary, abstract concepts, and implicit meaning relations. By moving beyond basic readability measures, this framework captures how meaning is structured in scientific discourse, providing an objective basis for understanding the demands placed on learners.

Figure 2

A conceptual framework for analysing linguistic complexity of reading texts in the 7th-grade general science textbook.

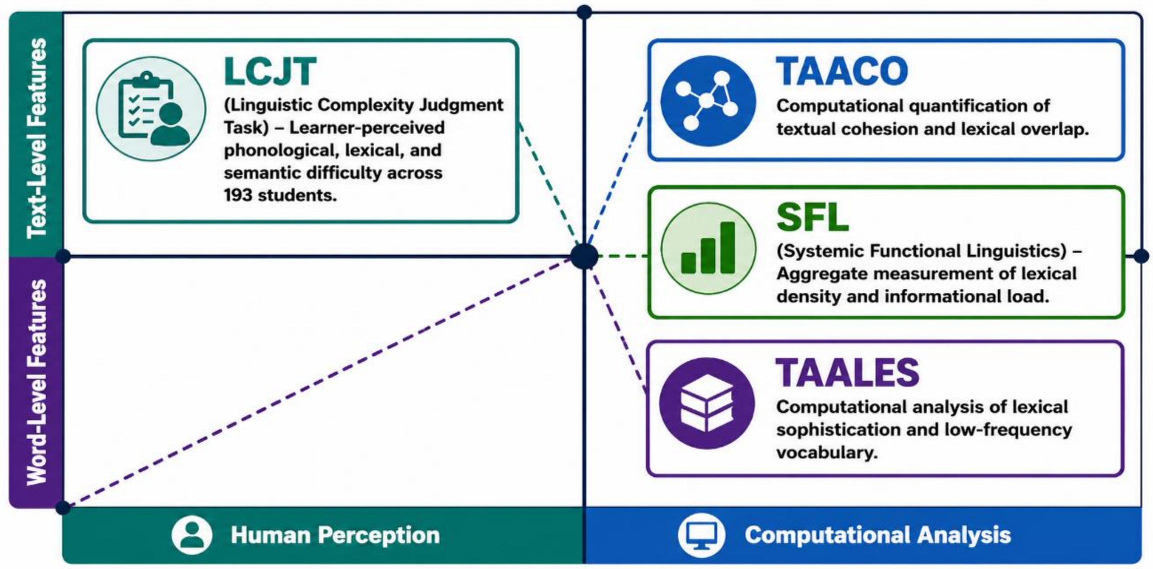


Figure 2 outlines the framework for analyzing linguistic complexity in seventh-grade general science texts, organized into four interrelated clusters. The first, linguistic complexity judgment criteria, combines phonological, lexical, and semantic dimensions within a threshold-based approach to classify difficulty. The second, grounded in systemic functional analyses, includes lexical density, abstraction, technicality, and familiarity, reflecting informational load and conceptual distance. The third, lexical sophistication, captures the use of low-frequency and specialized vocabulary. The fourth, semantic textual cohesion, includes lexical overlap, repetition, and type–token ratio, indicating how lexical recurrence and diversity shape coherence.

Objective linguistic complexity alone cannot account for differences in student outcomes, as learners interact with texts through their perceptions, beliefs, and motivation. The second framework examines how perceived linguistic competence and textbook complexity affect science achievement via engagement profiles, which mediate cognitive, behavioral, emotional, and agentic involvement. By capturing varying combinations of effort, persistence, interest, and strategic learning, these profiles provide a nuanced understanding of how perceptions of language ability and text difficulty shape engagement and, ultimately, achievement.

Integrating these two frameworks strengthens the study by linking objective and subjective factors. The textbook linguistic complexity framework defines the learning environment, while the engagement-based framework captures students' motivational and perceptual responses. By connecting text features with learner perceptions and engagement profiles, the study avoids attributing science achievement solely to texts or individual differences, instead highlighting how achievement emerges from the interaction among texts, learners, and engagement processes (see Figure 3).

Figure 3

A conceptual framework illustrating the effects of perceived linguistic competence and perceived textbook linguistic complexity on science achievement mediated by multidimensional engagement profiles.

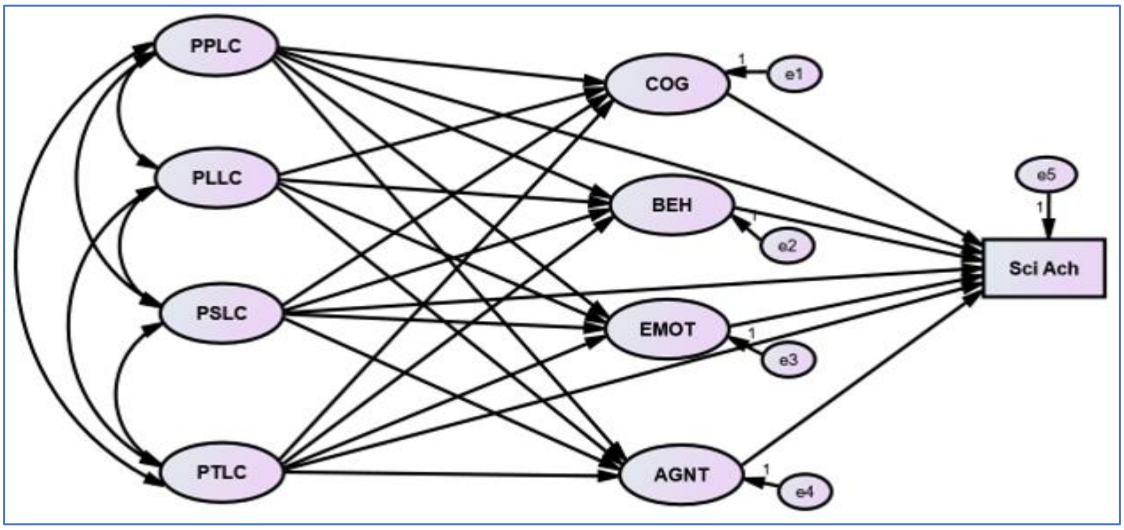


Figure 3 presents an integrated model showing how perceived linguistic competence and perceived textbook complexity influence science achievement through engagement profiles. Perceived personal linguistic competence (PPLC), perceived linguistic learning confidence (PLLC), perceived science linguistic complexity (PSLC), and perceived textbook linguistic complexity (PTLC) are depicted as interconnected antecedents. Bidirectional arrows indicate that students' self-perceptions and perceptions of textbook difficulty are mutually reinforcing rather than independent influences.

Perceptions of linguistic competence influence science achievement mainly by shaping student engagement. Engagement is modeled across four dimensions: cognitive (COG), behavioral (BEH), emotional (EMO), and agentic (AGTC). Cognitive engagement reflects effort in understanding complex scientific language; behavioral engagement captures participation and observable effort; emotional engagement represents affective responses like interest or anxiety; and agentic engagement reflects proactive contributions to learning.

Disturbance terms (e) account for unexplained variance, supporting the model's theoretical and statistical validity.

Finally, all engagement dimensions converge on science achievement (Sci Ach), positioned as the ultimate outcome on the right side of the framework. This arrangement highlights that achievement is not directly determined by linguistic perceptions alone, but by how these perceptions shape students' engagement profiles. By modeling multiple, simultaneous pathways from perceptions to engagement and from engagement to achievement, the framework illustrates a dynamic process in which linguistic self-beliefs and perceived textbook complexity influence academic outcomes through distinct engagement patterns.

2.10. Summary of the Literature Review

Theoretically, frameworks of academic language and disciplinary literacy (Halliday, 2009; Snow, 2010; Yore et al., 2003; Yore & Treagust, 2006) conceptualize language as a cognitive and epistemic resource for constructing scientific meaning rather than merely a communicative medium. Empirical findings support this view, showing that students perceived linguistic competence predicts engagement, self-efficacy, and achievement (Ardasheva et al., 2021; Neri & Retelsdorf, 2022; Hu et al., 2022). Nonetheless, most prior models focus on objective proficiency rather than subjective linguistic perceptions, leaving the indirect pathways between language competence, engagement, and science outcomes underexplored.

Empirical research shows that phonological, lexical, and semantic competence is crucial for science learning. Because science texts are linguistically and conceptually demanding, students' ability to understand and use scientific language strongly predicts performance, especially in middle school, when learners shift from general literacy to discipline-specific language. Linguistic competence supports decoding, comprehension, reasoning, and scientific discourse, highlighting the need for instruction that develops both language and scientific literacy through phonological awareness, vocabulary, and semantic reasoning (de Jong & van der Leij, 2002; Melby-Lervåg et al., 2012; Nation, 2022; Yun, 2020).

Research shows that textbooks' linguistic complexity, through dense syntax, advanced vocabulary, and cohesive discourse, places heavy cognitive demands on learners (Green, 2019; Berendes et al., 2018; Lodge, 2021). Yet, most studies describe these features without linking them to students' language skills or engagement. Since textbooks are key in science education, understanding how text complexity interacts with learner characteristics is crucial. Likewise, while engagement (behavioral, cognitive, emotional, and agentic) is known to mediate achievement (Fredricks et al., 2018; Uçar & Sungur, 2017; Grabau & Ma, 2017), few studies connect engagement, language competence, and textual features to science performance.

Research consistently shows that student engagement, a multidimensional construct including behavioral, cognitive, emotional, and agentic components, is a key predictor of science achievement (Fredricks et al., 2018; Uçar & Sungur, 2017; Grabau & Ma, 2017). Engaged students persist, explore, and participate more, improving comprehension, conceptual understanding, and problem-solving. Cognitive and agentic engagement drive inquiry and reasoning, while emotional engagement maintains motivation. Engagement also mediates the effects of linguistic competence, self-efficacy, and instructional quality on science performance (Feng & Hong, 2022; Yu et al., 2021).

Although engagement is known to predict learning outcomes, research often treats it as a single construct, ignoring how its dimensions differently affect achievement. Few studies examine engagement as a mediator between students' linguistic competence, text complexity, and science performance. This is especially important for middle schoolers navigating abstract, language-heavy curricula. Studies indicate that linguistically accessible instruction that supports competence and agency boosts engagement and achievement (Lee et al., 2016;

Achwani et al., 2025). Integrating engagement-focused strategies with linguistic scaffolding is therefore crucial, particularly in diverse classrooms.

Furthermore, research has predominantly emerged from Western and Asian contexts, with minimal evidence from African or Ethiopian settings where English or another foreign language serves as the medium of instruction. Ethiopian middle school students, in particular, face distinctive linguistic challenges transitioning from mother-tongue to English-medium science learning. Yet, no study has comprehensively examined how perceived linguistic competence, textbook linguistic complexity, and multidimensional engagement jointly influence their science achievement.

Although linguistic competence is well-studied, few studies explore how students' self-perceived linguistic ability, textbook complexity, and engagement together affect science achievement, despite evidence that language skills support comprehension, learning, and participation, and that self-perceptions influence motivation and persistence in early adolescence (Guglielmi, 2012; Uccelli et al., 2015; Ardasheva et al., 2021). This study addresses these gaps by examining the direct and indirect effects of perceived linguistic competence and textbook complexity on Grade 7 students' science achievement in Ethiopia through cognitive, behavioral, emotional, and agentic engagement.

CHAPTER THREE

METHODS AND MATERIALS

3. Introduction

This chapter outlines the methodological procedures used to examine effects of perceived linguistic competence and textbook linguistic complexity on science achievement via engagement profiles among seven-grade students. It presents the research design, population, and sampling procedures, followed by a description of the research instruments and their adaptation, validation, and reliability tests. The chapter also details the data collection procedures, data analysis techniques, assumption testing, and concludes with the ethical considerations.

3.1. Research Paradigm

The study was grounded in a post-positivist epistemological stance, emphasizing the role of observable evidence, while simultaneously recognizing that the researcher's own assumptions and values may shape aspects of the inquiry (Creswell, 2015).

3.2. Research Approach

The current research study employed a quantitative research approach. This approach is particularly important for developing and empirically testing theoretically driven hypotheses, facilitating the statistical analysis of numerical data, and enabling the generalization of results to a broader population (Creswell, 2015). Furthermore, it also allows the researchers to collect a large amount of data at a single temporal point through the use of structured questionnaires (Stockemer et al., 2019) and allows for the examination of interrelationships among variables within a defined population at a specific moment in time (Creswell, 2015).

As Creswell (2015) explains, quantitative inquiry is particularly well suited to examining how one variable affects another and to determining the extent to which specific factors can serve as predictors of an outcome variable. Quantitative approach also allows researchers to analyse complexity of reading texts, genres, and proficiency levels using standardized protocols, which is essential for curriculum design, readability assessment, and learner-appropriate text selection (McNamara et al., 2014).

3.3. Research Design

A correlational research design was chosen to examine relationships between variables without experimental manipulation, aligning with the goal of exploring how linguistic and engagement factors relate to science outcomes (Creswell, 2015). This design supports complex analyses, such as structural equation modeling, to assess interactive effects and predictor contributions (Hair et al., 2019), providing empirical links to inform theory and future interventions, though causality cannot be inferred (Thompson et al., 2005).

A quantitative content analysis was also used to examine linguistic complexity of reading texts in the seventh-grade science textbook, enabling objective identification, categorization, and frequency counting of textual features (Drisko & Maschi, 2016). Students' complexity judgments helped identify complex terminology, providing direct evidence of textbook complexity, a method supported by research in educational linguistics and readability studies (Green, 2019; Pilán et al., 2016; Snow, 2010; To, 2018).

The study used a cross-sectional survey design to collect data at a single point in time, examining how perceived linguistic competence and textbook linguistic complexity influence science achievement through engagement profiles among 7th-grade students. This design allows for the analysis of naturally occurring relationships among variables without experimental manipulation and is widely applied in educational and social science research for its efficiency in exploring correlations (Creswell, 2015).

3.4. Population of the Study

The target population comprised all Grade 7 students enrolled in schools within the Bahir Dar City Administration during the 2024 academic year (N = 9,880), including 5,323 female and 4,557 male students. These students were studying under the Ethiopian national curriculum at the middle school education level. The study included students from schools operating within the city administration, with the specific school type (public and private) determined by the study's sampling frame.

The study focused on seventh-grade students because this stage marks a critical transition in education where foundational concepts become more complex, making it an ideal point to assess learning outcomes and development (Destin & Williams, 2020). In Ethiopia, Grade 7 typically marks the beginning of EMI for science and the shift from primary to middle schooling. At this stage, students are introduced to abstract scientific terminology and discourse in English (Heugh et al., 2007; Seid, 2016). This abrupt transition may undermine students' confidence in their linguistic competence, as they often struggle to master the subject-specific language required to comprehend and articulate scientific concepts (Cummins, 2000).

Empirical evidence indicates that inadequate proficiency in the medium of instruction impedes cognitive engagement, reduces participation in inquiry-based activities, leads to disinterest, and lowers achievement outcomes in science (Probyn, 2019). Students' limited command of linguistic features, for instance, lack of proper pronunciation, unfamiliar technical lexis, and abstract concepts hinders conceptual retention, processing, and knowledge construction, perpetuating disengagement and underperformance (Schleppegrell, 2004).

The selection of Grade 7 students is developmentally justified, as early adolescence (ages 12–14) involves rapid cognitive and socio-emotional changes (Eccles & Roeser, 2011). At this stage, learners begin to develop abstract reasoning essential for scientific learning (Piaget, 1970). However, the linguistic demands of English-medium instruction may overload working memory and limit metacognitive processing (Siregar, 2023; Vygotsky, 1978), while also reducing academic self-efficacy and engagement (Britner & Pajares, 2006). As students progress and encounter increasing academic language demands in science, unresolved linguistic barriers may accumulate, leading to persistent learning gaps (Yun, 2020).

Focusing on middle school, therefore, allows for the identification of developmental sensitivities to language transition and supports timely intervention in multilingual contexts, while also enabling a clearer examination of how linguistic factors and engagement influence science achievement (Benson, 2013). The study area was chosen due to its proximity to Bahir Dar University and the researchers' prior familiarity with local instructional practices. Its accessibility also allowed the researchers and data collectors to make repeated visits and gather the required information timely and efficiently

3.5. Sample size determination and sample

A substantial sample size is widely recognized as essential for both multiple regression and structural equation modelling (Tabachnick & Fidell, 2001). The sample size for this study was determined from a target population of 7th-grade students. Yamane's (1967) formula for finite populations was applied to obtain the minimum required sample size, such as $n = N / 1+ N*e^2$, where **n** is the required sample size, **N** is the population size, and **e** is the margin of error, set at 0.05 to achieve a 95% confidence level, resulting 386 sample students. Sample size determination should be based on statistical considerations, such as power, effect size, and variability, rather than arbitrary percentages (Gan, 2025).

Minimum sample size formulas primarily emphasize estimation precision, but they do not fully capture the higher statistical demands of mediation and path analysis, which require larger samples to achieve stable parameter estimates and adequate power for detecting indirect effects. Evidence from Sim et al. (2022), based on a review of 206 mediation studies, indicates that sample sizes ranged from 73 to 13,645; for structural equation modeling (SEM) in general, the mean sample size was 500 and the median was 311, while studies employing path models reported a mean of 447 and a median of 266. These findings suggest that several hundred participants are typically needed for robust mediation analysis and reinforce the importance of exceeding minimum sample size thresholds when applying complex analytical techniques.

Consistent with these methodological recommendations, the sample size was increased to 500 students to improve statistical precision, to enhance the detection of smaller direct and indirect effects, and to ensure stable parameter estimates in SEM and path analysis (Sim et al., 2022). Larger samples also strengthen representativeness and support subgroup and sub-sample analyses (Cohen et al., 2002; Lohr, 2021). The increased sample size also accommodates an anticipated non-response rate of approximately 20%, yielding an estimated 474 usable responses while maintaining adequate statistical power (Draugalis et al., 2008; Levy & Lemeshow, 2013).

3.5.2. Sampling techniques and distribution

3.5.2.1. Multistage cluster sampling technique

A multistage cluster sampling technique was employed to ensure methodological rigor, feasibility, and representativeness of the study population within Bahir Dar City Administration. This approach is recommended when the target population is geographically dispersed across institutions and when complete individual-level sampling frames are difficult to obtain (Gebrewold et al., 2016; Lee et al., 2014; Levy & Lemeshow, 2008; Sedgwick, 2015).

In the first stage, eight schools were randomly selected from a total of 38, ensuring all schools, regardless of size or administrative context, had an equal chance of inclusion. In the second stage, 14 classrooms were randomly chosen within these schools to account for variability in classroom environments, teaching practices, and peer interactions. In the final stage, all students from the selected classrooms were included in the sample, following established probability sampling principles (Levy & Lemeshow, 2008; Sedgwick, 2015).

A sample of 523 students was found from the 14 selected classrooms. Each student was then assigned a coded identifier corresponding to their official school roster number to facilitate accurate matching when collecting their semester science average scores (science achievement), while maintaining confidentiality during data handling. As presented in Table 2, the distribution of the 523 study participants reflects school type, gender, and grade level. Of the total sample, 349 students (66.73%) were drawn from public schools, while 174 students (33.27%) were from private schools, reflecting the dominant role of public schools in Bahir Dar City Administration. This proportional representation of school types enhances the sample's representativeness and reduces potential sampling bias in population estimates (Ahmed, 2024; Levy, & Lemeshow, 2013; Lohr, 2021).

Regarding gender, the sample comprised 296 female students (56.60%) and 227 male students (43.40%). This composition arose naturally from the random sampling procedure and mirrors enrolment patterns in the selected schools, rather than being imposed by a predetermined quota. Allowing gender representation to follow actual enrolment strengthens external validity and supports generalization of findings to the broader student population.

Table 2

Distribution of study participants by school type and gender before data cleaning and final analysis

School	School Type	Participants	Female	Male
Teyma	Public	71	39 (54.93%)	32 (45.07%)
Sertsedingil	Public	66	35 (53.03%)	31 (46.97%)
Shimbit	Public	73	41 (56.16%)	32 (43.84%)
Kulkual	Public	70	36 (51.43%)	34 (48.57%)
Science Amba	Public	69	33 (47.83%)	36 (52.17%)
	Public Total	349	184 (52.72%)	165 (47.28%)
Catholic	Private	63	42 (66.67%)	21 (33.33%)
SOS	Private	54	35 (65.45%)	19 (31.15%)
Bahir Dar Academy	Private	57	35 (60.34%)	22 (39.66%)
	Private Total	174	111 (63.79%)	63 (36.21%)
Total	Grand total	523	296 (56.60%)	227 (43.40%)

3.5.2.2. Stratified sampling technique

From the dataset of 500 students, a stratified subsample of 210 participants was selected through a lottery procedure to ensure proportional representation of achievement levels within each classroom. Although Ethiopian educational policy does not formally define low, medium, and high achievement labels, the widespread use of percentage-based grading provides a practical and empirically supported basis for grouping students according to academic performance (Abebe et al., 2017).

In each of the 14 classes, students' second semester science scores were organized based on the Ethiopian percentage grading system and grouped into three achievement categories, such as low achievement (below 50), medium achievement (50–74), and high achievement (75–100) (Ayalew et al., 2020). These categories reflect common grading practices in Ethiopian schools, where percentage scores are the standard method for reporting academic performance and scores of 50 and above are considered passing (Tiruneh et al., 2021). For analysis purposes, students were therefore classified as high-achieving (75–100), medium-achieving (50–74), and low-achieving (below 50).

Following classification, five students were randomly selected from each performance group within every class using a lottery method based on coded identifiers. This produced 15 students per classroom and a total subsample of 210 participants. The two-stage sampling design, combining initial random selection with stratified random sampling by achievement level, enhanced representativeness while ensuring balanced comparability across performance groups (Ahmed, 2024; Sedgwick, 2015). After data cleaning, 17 responses were excluded due to incompleteness or inconsistencies, resulting in a final analytic sample of 193 students, including 87 males and 106 females, aged approximately 13 to 16 years (see Table 3).

This targeted subsample was necessary because in-depth analyses of linguistic complexity require cognitively demanding tasks, such as text-based judgment tasks, comprehension probes, or feature-specific evaluations, that are impractical to administer to the entire large sample without compromising data quality or participant engagement (Rea & Parker, 2014). Research on survey burden and cognitive load suggests that intensive linguistic or textual analyses are most effectively conducted with a manageable subsample, ensuring attentive participation and reliable responses (Teddlie & Yu, 2007; Willis, 2018).

Table 3

Participants' demographic information for the two samples (n = 500, n= 193)

			Main sample (n = 500)			
Demographic Variable	Category	N	%	Mean	Range	SD
	Male	214	42.80%			
Gender	Female	286	57.20%			
Age				13.91	13-17	.898
	Private	171	34.20%			
School Type	Public	329	65.80%			
			Sub-sample (n = 193)			
Gender	Male	87	45.10%			
	Female	106	54.90%			
Age				14.02	13-16	.829
	Public	124	64.25%			
School Type	Private	69	35.75%			

The first sample (n = 500) included 214 males (42.8%) and 286 females (57.2%) with an average age of 13.91 years (range 13–17, SD = 0.90). Most students attended public schools (65.8%), while 34.2% were enrolled in private schools. The sub-sample (n = 193) selected for in-depth analyses had a similar demographic profile, comprising 87 males (45.1%) and 106 females (54.9%) with a mean age of 14.02 years (range 13–16, SD = 0.83). In this group, 64.3% were from public schools and 35.8% from private schools.

3.5.2.3. Content sampling

Content sampling with simple random procedure was also used to select reading texts from the 7th-grade general science textbook. 7th-grade General Science Textbook comprises seven units with 59 reading texts, with a total of approximately 11,983 words, consisting of continuous narrative explanations, introductions, definitions, histories, and descriptions, while excluding activities of experiments, review questions, project work instructions, summaries, figures, and tables (see Table 4). Each explanatory section was considered a distinct reading text unless it formed an uninterrupted continuation of the preceding section, thereby helping readers stay focused and engaged while preserving content diversity and representativeness.

Table 4

Grade 7 General Science textbook with number of units, approximate texts and words

Units	Unit topics	Approximate No. of Reading Texts	Approximate No. of Words
Unit 1	Basic Concepts of Science	5	717
Unit 2	Matter in Our Surroundings	12	2141
Unit 3	Elements, Compounds & Chemical	11	1532
Unit 4	Cell as the Basis of Life	10	2132
Unit 5	Living Things and their Diversity	8	2023
Unit 6	The Earth	6	1757
Unit 7	Force, Motion and Energy	7	1681
	Total approximate texts and words	**59**	**11, 983**

Four texts were randomly sampled from the seven instructional units included in the 7th-grade General Science textbook using the lottery method, ensuring coverage of diverse topics and formats to provide a representative overview without overwhelming respondents. Limiting the sample to four texts reduces participant fatigue, boredom, and careless responses, thereby maintaining data quality and feasibility within practical time and cost constraints (Jackson & Trochim, 2002; Rea & Parker, 2014). Moreover, a smaller and manageable number of sample texts allows respondents to engage more deeply with each text, leading to more thoughtful and accurate responses (Rea & Parker, 2014).

Accordingly, Text 1 was randomly selected from Unit 4, Text 2 from Unit 1, Text 3 from Unit 5, and Text 4 from Unit 7. To mitigate the small sample of reading texts, quantitative linguistic analyses using TAALLESS and TAASCO, combined with students' complexity judgments, were employed to ensure that observed patterns accurately represent the linguistic features across all 59 texts. Lexical diversity was assessed by counting the number of unique words in each text in which Text 1 contained 53, Text 2 contained 98, Text 3 contained 106, and Text 4 contained 55 unique words (see Table 5).

Table 5

Corpus size and lexical characteristics of the sampled reading texts

Reading Text	Total Words (Tokens)	Unique Words (Types)	% of Total Corpus (537)	Type-Token Ratio (TTR)
Text 1	69	53	12.80%	.770
Text 2	183	98	34.10%	.540
Text 3	165	106	30.70%	.640
Text 4	120	55	22.30%	.460
Total	537	312	100.00%	-

Table 5 shows variation in both length and lexical diversity across the four texts, which together comprised 537-word tokens and 312 unique word types. Text 2 was the longest with 183 tokens (34.10% of the corpus), followed by Text 3 with 165 tokens (30.70%), Text 4 with 120 tokens (22.30%), and Text 1 with 69 tokens (12.80%). Lexical diversity, measured by the Type–Token Ratio (TTR), was highest in Text 1 (TTR = 0.770), followed by Text 3 (TTR = 0.640), Text 2 (TTR = 0.540), and Text 4 (TTR = 0.460). Although Texts 2 and 3 were the longest, Text 1 contained the richest unique vocabulary relative to its length, while Text 4 exhibited the most lexical repetition. The total of 537 words had a TTR of .580.

3.6. Data Collection Instruments

Multiple instruments were employed to collect data in the present study. The procedures and measures used for data collection are described below.

3.6.1. Questionnaires

The study used three closed-ended Likert-scale questionnaires to collect data. Two instruments, developed by the researchers, measured students' perceived linguistic competence and their perceptions of textbook linguistic complexity, assessing self-reported linguistic ability and the linguistic demands of science textbooks. Item development was guided by relevant literature and aligned with the constructs of interest. The third instrument, the Students' Engagement in Science Learning (SESL) scale, was adapted from a validated measure to examine students' engagement in science learning. All instruments were piloted with a sample from the target population to evaluate clarity, relevance, and comprehensibility, and minor revisions were made based on feedback to improve clarity and content validity before final administration.

The study used three instruments, such as the Perceived Linguistic Competence Scale (PLCS), the Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ), and the Students' Engagement in Science Learning (SESL) scale. The PLCS and PTLCQ employed a five-point Likert scale ranging from 1 (Not True at All) to 5 (Very True) following DeVellis's (2017) scale development guidelines, while the SESL used a five-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree) to measure students' engagement in science learning.

3.6.1.1. The perceived linguistic competence scale (PLCS)

The Perceived Linguistic Competence Scale (PLCS) was developed by selecting and integrating items from established instruments. These included the Perceived Language Competence Scale (Luo et al., 2019; $\alpha = 0.71–0.85$; e.g., "I can understand new scientific vocabulary in context"), the Perceived Competence Scale (Williams et al., 1998; $\alpha = 0.78–0.93$; e.g., "I feel capable of performing tasks in my field of study"), and the Self-Perceived Communication Competence Scale (SPCC) (McCroskey & McCroskey, 1988; $\alpha \approx 0.90$; e.g., "I am confident explaining scientific concepts orally to others"). Additionally, items were guided by the CEFR Self-Assessment Grid (Council of Europe, 2001; e.g., “I can understand the main ideas in a science lecture on topics I know”) to capture self-perceived proficiency across listening, reading, speaking, and writing.

These measures assessed students’ self-perceived ability to handle linguistic features while learning content subjects, including confidence in pronouncing and recognizing scientific terminology, interpreting meanings, and expressing ideas during discussions. In language and education research, such perceptions reflect learners’ confidence in processing linguistic input and managing communication demands in learning contexts (Nation, 2013). Students rated statements about their confidence in their linguistic competence during learning science on a five-point Likert scale (1 = Not True at All to 5 = Very True), consistent with prior research showing that self-assessed language competence is meaningfully linked to academic adaptation, engagement, psychological well-being, and achievement (Luo et al., 2019; Nation, 2013; Williams et al., 1998).

The measure used in this study aligns with established practices for assessing perceived linguistic competence via structured self-report indicators. It comprises three subscales: phonological competence (seven items on pronunciation and articulation, e.g., “I am able to correctly pronounce terminologies in the general science textbook,” $\alpha = .810$), lexical competence (nine items on familiarity and effective use of terms, e.g., “I can access most of the words in the science textbook,” $\alpha = .950$), and semantic competence (five items on meaning and inter-word relationships, e.g., “I can understand the contextual meaning of scientific terminologies,” $\alpha = .850$). The overall scale demonstrated excellent internal consistency with a Cronbach’s α of .920.

3.6.1.2. The perceived textbook linguistic complexity questionnaire (PTLCQ)

The Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ) was also developed by selecting relevant items from the Perceived Language Competence Scale (Luo et al., 2019; α = 0.71–0.85; e.g., “I can understand new scientific vocabulary in reading texts of the textbook”), the Perceived Competence Scale (Williams et al., 1998; α = 0.78–0.93; e.g., “I feel capable of understanding the explanations in my science textbook”), Self-Perceived Reading or Text Comprehension Scales (Snow, 2010; Li et al., 2022; e.g., “I can identify the main ideas in a science text without help”), and items informed by Thome et al. (2024; α is not reported) (e.g., “I find sentences in my science textbook difficult due to technical vocabulary”). The scale captures students’ perceived difficulty in vocabulary, sentence structure, and conceptual density, using a five-point Likert-type scale from 1 (Not true at all) to 5 (Very true).

The PTLCQ consisted of nine items measuring how difficult students perceive the language of their science textbooks, and exploratory factor analysis (EFA) showed that all items reflect a single underlying construct, indicating that students experience language difficulty as one overall impression. Students reported that textbook words are often too technical and that they frequently encounter unfamiliar terms, and the scale showed high reliability with a Cronbach’s alpha of 0.94. This unidimensional approach is appropriate because research indicates that readers typically perceive text difficulty holistically (Williams et al., 1998; Nation, 2013) rather than as separate components like vocabulary or meaning, with features such as technical language, complex wording, and dense ideas combining into a single sense of overall linguistic demand (Shardlow et al., 2022).

3.6.1.3. Students’ engagement in science learning (SESL) scale

The Student Engagement in Science Learning (SESL) Scale (Li et al., 2024) was developed drawing on established literature (Fredricks et al., 2004, 2016; Reeve & Tseng, 2011) and items from the Student Engagement Instrument (SEI; Appleton et al., 2006) and Agentic Engagement Scale (Reeve, 2013). It includes 33 items across four dimensions: cognitive (α = 0.82; e.g., “I try to understand science concepts deeply”), emotional (α = 0.85; e.g., “I enjoy learning science topics”), behavioral (α = 0.81; e.g., “I participate actively in class activities”), and agentic (α = 0.88; e.g., “I ask questions or suggest ideas to improve my learning”). Items are rated on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), with higher scores indicating greater engagement. The scale has been validated in diverse contexts, confirming a four-factor structure consistent with theoretical models of student engagement.

In the present study, the SESL was administered to assess students’ self-reported engagement profiles in science lessons, providing a multidimensional view of comprehension, participation, interest, and initiative in learning activities. The scale demonstrated high internal consistency, with Cronbach’s alpha exceeding 0.70 for the total scale and all subscales: cognitive engagement (α = 0.94; 11 items, e.g., “I get focused while doing science tasks”), behavioral engagement (α = 0.81; 9 items, e.g., “I always participate in discussions during science learning”), emotional engagement (α = 0.90; 7 items, e.g., “I feel excited when learning new things in science”), and agentic engagement (α = 0.93; 6 items, e.g., “I try different strategies until I understand concepts in the general science textbook”), demonstrating high reliability across all dimensions..

3.6.1.4. Linguistic complexity judgment task (LCJT)

Readability formulas such as Flesch–Kincaid, SMOG, and Gunning Fog are widely used to estimate textual difficulty, but research shows they have limited ability to predict students’ comprehension of scientific texts (Kincaid et al., 1975; Moschitti & Basili, 2004). These formulas primarily rely on surface-level features, including word length, sentence length, and syllable count, based on the assumption that longer linguistic units increase cognitive load (Zhou et al., 2017). Yet, evidence indicates that these variables explain only a small portion of the variation in students’ comprehension outcomes. Deeper semantic and syntactic complexity, are significantly predicts students’ reading performance (Nadeem &

Ostendorf, 2018). As a result, readability formulas often underestimate the difficulty of texts that are conceptually dense, abstract, or contain unfamiliar vocabulary (Yahya et al., 2023).

Word knowledge goes beyond simply recognizing words; it involves understanding meanings in context, noticing subtle semantic differences, and using words accurately across disciplines, reflecting sensitivity to deeper linguistic and semantic structures (Nadeem & Ostendorf, 2018; Novianti & Syihabuddin, 2021; Schmitt, 2014). Likewise, phonological awareness, often overlooked by standard readability formulas, affects comprehension, engagement, and academic performance (Gutiérrez-Palma et al., 2019; Kieffer & Lesaux, 2007, 2012). Research shows that surface-level metrics alone fail to capture the linguistic features that create conceptual difficulty (Fitzgerald et al., 2017; McComas, 2013).

Given these limitations, using learners' own judgments of linguistic complexity provides a more direct and ecologically valid way to assess textbook linguistic complexity. By having students indicate which phonological, lexical, or semantic elements they find challenging, researchers gain insight into the factors that actually hinder comprehension (Best et al., 2005). This approach captures the cognitive load experienced during real reading, highlighting elements that reduce engagement and may affect achievement. Unlike traditional readability formulas, which often overlook individual differences, student judgments offer actionable information for instruction and support differentiated teaching (Carlson et al., 2003; Lee & Lee, 2023). Thus, a full understanding of linguistic complexity benefits from combining learner evaluation with computational linguistic textual analysis.

To implement this approach, the present study used a Linguistic Complexity Judgment Task (LCJT), adapted from the Text Complexity Annotation Task (Braylan et al., 2022). The LCJT has been applied in vocabulary and reading research to obtain systematic human evaluations of the linguistic demands in texts (Nation, 2013; Schmitt, 2014; Sun, 2020). Beyond serving as a primary measure, learners' judgments were used to triangulate quantitative complexity indices, ensuring that assessments of difficulty reflected both automated metrics and students' actual experiences (Nation, 2013; Stahl et al., 2019; Zhang & Lu, 2024). This combination of student evaluation and computational linguistic textual analysis provides a reliable framework for distinguishing between features that are structurally complex and those genuinely perceived as complex by students.

In the present study, 193 students were instructed to read four selected reading texts and marked words they found linguistically complex, categorizing each as phonological, lexical, semantic, or multidimensional. This method captured students' evaluations during authentic reading, allowing researchers to pinpoint specific linguistic features that may hinder comprehension, reduce engagement, or affect achievement in science. The approach is well suited for content-area literacy research, where conceptual and linguistic demands interact dynamically within academic texts (Nation, 2013; Schmitt, 2010; Sun, 2020).

Following established learner-judgment protocols (Crossley et al., 2012, 2016; Fang, 2016; Laufer, 2013, 2016; Ng et al., 2020), words were classified as complex when at least 50% of participants identified them as difficult in any dimension, including phonological, lexical, semantic, or their combinations. A stricter, researcher-defined high-consensus criterion was used to classify highly complex words, with items marked as difficult by at least 70% of participants in any dimension (Laufer, 2013, 2016). Applying a more conservative 40% threshold, commonly used in analyses of disciplinary science texts, yielded highly similar results, supporting the robustness and stability of the complexity criteria (Fang, 2016).

3.6.1.6. Science achievement

A single science test or exam may not accurately reflect middle school students' overall performance, as it only provides a brief picture of their learning (Brady-Amoon & Fuertes, 2011). To obtain a more reliable measure, cumulative science scores were used, combining results from multiple assessments throughout the semester. These scores offer a comprehensive view of learning outcomes by reflecting consistent performance over time rather than a single test (Richardson et al., 2012). Derived from written exams, quizzes, practical lab work, project-based tasks, and final exams, cumulative scores capture students' understanding of scientific concepts and performance in both theoretical and practical activities (Caspersen et al., 2017). The 7th-grade students' semester science scores were obtained from official school records, which compile verified assessment results for each semester.

3.6.2. Content analysis

This study employed a theory-driven quantitative content analysis to examine the linguistic complexity of reading texts drawn from the 7th-grade general science textbook, grounded in science literacy frameworks and multidimensional models of text complexity. Quantitative content analysis was selected because it enables the systematic, objective, and replicable coding of linguistic features into measurable indicators of textual demand, allowing complexity to be analyzed beyond traditional readability formulas based solely on sentence and word length (Krippendorff, 2018; Neuendorf, 2017). Instructional reading texts from the general science textbook were selected, with each text serving as a unit of analysis.

Unlike conventional readability approaches, this framework examined multiple dimensions of linguistic complexity at the word level, incorporating phonological, lexical, and semantic features relevant to science learning and comprehension. Individual words were therefore treated as the primary coding units and systematically classified across these three dimensions. Phonological complexity represented decoding and pronunciation demands associated with lower-level word recognition; lexical complexity captured unfamiliar, technical, and low-frequency scientific vocabulary; and semantic complexity reflected conceptual density, abstraction, and meaning-related difficulty associated with higher-order comprehension processes emphasized in science literacy (Fang, 2016; Norris et al., 2008).

3.7. Instrument Administration

Data were collected using structured, self-administered questionnaires with Likert-type items, a complexity judgment task, and content analysis. Before administration, students were informed about the study purpose and given clear instructions. Standardized procedures were applied across all classrooms to ensure consistency and minimize measurement error. All instruments were developed, validated, and adapted following established methodological procedures to ensure reliability and validity.

3.7.1. Data collection personnel and training

Data were collected by the principal researcher and a PhD candidate in Educational Psychology. The candidate, selected for his prior experience in survey-based data collection, assisted in ensuring accurate and consistent administration of the instruments. Prior to data collection, he received training on the study objectives, key variables, instrument structure, and standardized procedures. This preparation helped reduce bias and ensure uniformity and consistency across all data collection sites.

3.7.2. Institutional facilitation

School administrators, particularly the vice director, together with classroom teachers, supported the data collection process by coordinating classroom access, scheduling, and facilitating the orderly administration of questionnaires. Their role was strictly logistical and did not involve administering the instruments or handling completed responses. This separation of duties helped ensure participant confidentiality and reinforced the voluntary nature of student participation.

3.8. Instrument Validation

Instrument validation is a critical methodological step that ensures an instrument accurately measures its intended construct with consistency and theoretical alignment (DeVellis, 2021; Cronbach, 1951). It enhances accuracy and interpretability by confirming that results reflect the construct rather than error or irrelevant factors (Clark & Watson, 2019). Validation involves assessing face validity, content validity, construct validity through factor analysis, and criterion validity via related measures, alongside reliability to ensure consistency and stability (DeVellis, 2021; Kline, 2023; Brown, 2015). Conducting these tests, especially in pilot studies, enhances rigor, reduces measurement error, and supports credible conclusions (Boateng et al., 2018).

3.8.1. Cross-cultural translation and adaptation of Likert-scale survey

The translation and cultural adaptation of research instruments are essential for ensuring conceptual equivalence, linguistic accuracy, and cultural relevance when applied in new contexts, such as Ethiopia. In this study, the translation, development, and adaptation process followed internationally recognized guidelines for cross-cultural instrument adaptation proposed by Beaton et al. (2000), which are widely used and methodologically appropriate.

According to Beaton et al. (2000), cross-cultural adaptation involves a systematic multi-stage process to preserve the instrument's psychometric integrity while ensuring cultural appropriateness. This includes forward translation, synthesis, backward translation, expert review, and pretesting, aiming to achieve semantic, idiomatic, experiential, and conceptual equivalence between source and target versions (Cruchinho et al., 2024).

The first stage involved independent forward translation of the instruments from English into Amharic by four bilingual translators whose mother tongue was Amharic and who were highly proficient in both languages. Two were English language instructors and two were linguistics instructors at Bahir Dar University, each with over ten years of experience. Two translators had subject-matter expertise in psychological and linguistic measurement, ensuring conceptual accuracy, while the other two had no research background, minimizing bias. This independent approach helped capture alternative phrasing, identify ambiguities, and improve linguistic and conceptual accuracy (Beaton et al., 2000; Bispo & Perdigão, 2022).

Following independent forward translation, the two Amharic versions were systematically compared and merged into a single harmonized version through item-by-item review. Discrepancies were resolved through researcher-guided discussion, referencing the original English instruments, with emphasis on semantic, idiomatic, experiential, and conceptual equivalence as well as cultural clarity. Consensus decisions were documented, producing a synthesized version for subsequent backward translation (Beaton et al., 2000).

After synthesis, the reconciled Amharic version underwent backward translation to verify accuracy and detect meaning shifts. Two bilingual university instructors in Teaching English as a Foreign Language, each with over ten years of experience and no prior involvement in translation, independently back-translated the version into English while blinded to the original instruments. The back-translations were compared with the originals to identify discrepancies, serving as a quality control step to ensure conceptual fidelity and accuracy (Beaton et al., 2000).

Finally, following backward translation, all versions of the instruments were reviewed by experts consisting of the two supervisors of the study, both of whom are expertise in educational and developmental psychology, research methodology, and psychological measurement. They assessed semantic, idiomatic, experiential, and conceptual equivalence, as well as item clarity and cultural relevance. Revisions were made based on their feedback, producing the pre-final Amharic versions for further validation (Beaton et al., 2000).

3.8.2. Content validity test

Content validity ensures indicators are theoretically coherent, domain-appropriate, and free from irrelevant variance, supporting accurate measurement of structural relationships (Kline, 2023). In this study, ten experts from Bahir Dar University reviewed all items for theoretical alignment, cultural relevance, and suitability for 7th-grade students. The items were conceptually sound and comprehensible, requiring only minor lexical refinements, for example, “terminologies” → “scientific terminologies/science words,” “interpret” → “comprehend/understand,” and “complicated” → “difficult/complex.”

Each expert independently rated all items for relevance on a four-point Likert scale (1 = not relevant to 4 = highly relevant) and for clarity using a parallel scale (1 = not clear to 4 = very clear). Quantitative content validity indices were calculated using item-level (I-CVI) and scale-level (S-CVI) methods based on Lawshe (1975). I-CVI values ranged from 0.81 to 1.00, indicating high relevance for individual items (Ayre & Scally, 2013).

Item-level content validity (I-CVI) ranged from 0.81 to 1.00, while scale-level content validity (S-CVI/average) was 0.98 for the PLCS, 0.97 for the PTLCQ, 0.99 for the SESL, and 0.87 for the LCJT, indicating excellent content coverage. Clarity scores for individual items also ranged from 0.81 to 1.00, with corresponding S-CVI/average values of 0.98 (PLCS), 0.97 (PTLCQ), 0.98 (SESL), and 0.94 (LCJT). Items with lower clarity or relevance were revised based on expert feedback, ensuring their suitability for the research context (see Table 6).

Table 6

Content Validity Index (CVI) for Relevance and Clarity

Instruments	Relevance		Clarity	
	I-CVI range	S-CVI /ave.	I-CVI range	S-CVI/ave.
1. PLCS	.81 - 1.00	.98	.81 - 1.00	.98
2. PTLC	.81 - 1.00	.97	.81 - 1.00	.97
3. SELS	.81 - 1.00	.99	.81 - 1.00	.98
4. LCJT	.78 – 1.00	.87	.90 - 1.00	.94

Note: *PLCS, perceived linguistic competence scale; PTLCQ, perceived textbook linguistic complexity questionnaire; SESL, students' engagement in learning; LCJT, linguistic complexity judgement task; I-CVI = item level content validity index; S-CVI = scale level content validity index, S-CVI/ave. = the average of proportion relevance scores across all experts*

Content validity for the Linguistic Complexity Judgment Task (LCJT) was established to ensure that the task accurately captured students' judgments of linguistic complexity in selected reading texts in the General Science textbook. A 10-member expert panel, five science education specialists and five applied linguists, independently evaluated the texts for balanced domain representation, labeling protocols, instructional directives, and procedural clarity (Messick, 1995; Polit & Beck, 2006). Using a structured checklist, experts rated each component for relevance, representativeness, clarity, and coverage adequacy. Experts rated each text using a standardized relevance scale, and the ratings were used to compute item-level content validity (I-CVI) for each text and scale-level content validity (S-CVI) for the overall set of materials. This procedure ensured systematic evaluation of the suitability of the texts for representing linguistic complexity in Grade 7 science instruction.

Following content validation, a pilot study was conducted to assess the construct validity and reliability of the instruments. This phase ensured that items functioned as intended and accurately represented the theoretical constructs (DeVellis, 2017; Boateng et al., 2018). Reliability testing examined internal consistency, while construct validity, evaluated through exploratory and confirmatory factor analyses, determined whether the observed data reflected the hypothesized latent structures (Collier, 2020; Kline, 2023).

3.8.3. Pilot study

After establishing content validity, a two-phase pilot study was conducted to ensure the instruments' psychometric soundness and the feasibility of survey analyses. The first phase used exploratory factor analysis (EFA) to examine the instruments' factorial structure, evaluate initial item performance, and identify items with low loadings or communalities for revision or removal. Findings from this phase guided refinement of the instruments to achieve stable and interpretable factor structures.

The second pilot study evaluated the refined instruments by examining internal consistency and reliability, and provided further evidence of construct validity through preliminary confirmatory factor analysis (CFA). It also assessed the feasibility of the proposed structural equation modeling (SEM) framework by generating initial estimates of model parameters, variances, and effect sizes. The two pilot phases facilitated systematic instrument refinement, minimized measurement error, and ensured the methodological and statistical robustness of the measurement and structural models before the main study.

3.8.4. Factor analysis

In the pilot study, the scales for perceived linguistic competence, perceived textbook linguistic complexity, and engagement profiles were validated using both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), supporting subsequent structural equation modeling. Because the scales were newly developed or adapted from multiple sources and their factor structures were initially unknown, EFA was conducted first, followed by CFA.

3.8.4.1. Exploratory factor analysis (EFA)

A pilot study involving 200 students (107 females and 93 males) was conducted for Exploratory Factor Analysis (EFA), consistent with recommendations that samples of 100–200 participants are generally adequate, with larger samples providing more stable results (Marsh et al., 2009). EFA was employed to identify the latent structure of the scales, determine factor groupings, and eliminate items with low or cross-loadings (Tabachnick & Fidell, 2001).

Exploratory Factor Analysis (EFA) was conducted following established psychometric guidelines. Sample adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity (Cerny & Kaiser, 1977). Principal Axis Factoring with Promax rotation was applied to the PLCS, PTLCQ, and SESL scales. Factors were retained based on eigenvalues >1, scree plots, and parallel analysis. Items with loadings <0.40 or communalities <0.30 were removed, and reliability was confirmed using Cronbach's alpha coefficients ≥0.70 (Cronbach, 1951; Hair et al., 2014; Tabachnick & Fidell, 2001).

Exploratory factor analysis for the perceived linguistic competence constructs

The Perceived Linguistic Competence Scale (PLCS) was developed through a systematic literature review to ensure strong theoretical and empirical grounding (Boateng et al., 2018). Although linguistic competence is multidimensional, this study focused on phonological, lexical, and semantic dimensions, which are critical for science learning as they support decoding specialized terminology, accessing precise vocabulary, and constructing meaning from concept-dense texts (Snow, 2010; Wellington & Osborne, 2001). Limiting the scale to these dimensions also enhances response quality, maintains an adequate subject-to-item ratio for EFA, and ensures a reliable, interpretable factor structure (Hair et al., 2014).

Exploratory factor analysis used Principal Axis Factoring with Promax rotation due to expected factor correlations. Factorability was confirmed by adequate inter-item correlations (.341–.722), excellent sampling adequacy (KMO = .946), and a significant Bartlett's Test of Sphericity, χ^2 (210) = 4176.507, $p < .001$ (Hair et al., 2014; Tabachnick & Fidell, 2001). Retention criteria supported a three-factor solution, with eigenvalues >1.00 and a scree plot showing a sharp drop after the third factor (see Appendix E).

The final factor solution showed a clear, stable structure and strong construct validity, confirming that perceived linguistic competence consists of three dimensions: phonological, lexical, and semantic. Items with low communalities (PPLC7, PPLC11, PSLC19) were removed, resulting in a refined 21-item scale with strong communalities, coherent factor loadings, no cross-loadings, and all items exceeding the recommended .30 communalities threshold (DeVellis, 2017).

Table 7 confirms the refined 21-item scale's stability, construct validity, and internal consistency, supporting its use in further reliability testing and confirmatory factor analysis (DeVellis, 2021). Reliability was high, with Cronbach's alpha of .91 (phonological), .94 (lexical), .93 (semantic), and an overall internal consistency of.93. The three factors explained approximately 72% of total variance and 66% of common variance, with rotated variance distributed as 31.37%, 23.58%, and 19.13%, improving interpretability.

Table 7

Rotated factor matrix, communalities for PLCS (n = 200)

Indicators	Factor Loadings			Communalities	
	Factor 1	Factor 2	Factor 3	Initial	Extraction
PPLC 1	.832			.771	.791
PPLC 2	.811			.711	.732
PPLC 4	.831			.762	.782
PPLC 3	.814			.773	.781
PPLC 5	.831			.773	.794
PPLC 6	.722			.512	.532
PPLC 10	.841			.792	.813
PLLC 8		.750		.744	.763
PLLC 9		.762		.673	.681
PLLC 12		.821		.773	.781
PLLC 13		.803		.712	.744
PCLC 15		.781		.701	.724
PLLC 14		.811		.704	.732
PLLC 16		.832		.724	.754
PLLC 17		.773		.731	.753
PLLC 18		.813		.762	.792
PSLC 21			.781	.713	.722
PSLC 20			.813	.772	.801
PSLC 22			.832	.814	.851
PSLC 23			.851	.862	.884
PSLC 24			.842	.813	.841
Cronbach's alpha	.912	.943	.933		
Total Cronbach's alpha	.932				

Exploratory factor analysis for the perceived textbook linguistic complexity construct

The Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ) was initially a 12-item unidimensional measure. Principal axis factoring identified three weak items (Ptlc5, Ptlc9, Ptlc11), which were removed. The remaining nine items produced a clear single-factor solution, with one factor exceeding the Kaiser criterion (eigenvalue = 6.345), explaining 70.50% of total variance and 66.99% of common variance.

Factorability was confirmed by moderate to strong inter-item correlations (.435–.702), excellent sampling adequacy (KMO = .953), and a significant Bartlett's Test of Sphericity, χ^2 (36) = 1475.726, $p < .001$ (Tabachnick & Fidell, 2001). Communalities were substantial both before (.567–.790) and after extraction (.559–.811), indicating that the retained items shared meaningful variance and were well represented by the single latent factor, thereby supporting the conceptualization of perceived textbook linguistic complexity as a coherent, one-dimensional construct (see table 8).

Table 8

Rotated factor matrix, communalities for PTLCQ (n = 200)

	Factor Loadings	Communalities	
Indicators	**Perceived textbook linguistic complexity**	**Initial**	**Extraction**
PTLC1	.822	.658	.676
PTLC3	.836	.672	.698
PTLC7	.779	.602	.607
PTLC8	.861	.726	.742
PTLC6	.888	.768	.789
PTLC10	.678	.567	.559
PTLC2.	.900	.790	.811
PTLC4	.804	.628	.646
PTLC12	.775	.591	.601
Cronbach's alpha	.941		

Exploratory factor analysis for the constructs of engagement profiles

An exploratory factor analysis of the Students' Engagement in Science Learning Scale, designed to assess cognitive, behavioral, emotional, and agentic engagement, used principal axis factoring to model shared variance (Fabrigar & Wegener, 2011). The initial 38-item analysis showed adequate factorability (inter-item correlations .426–.679). Five items (Agetc29, Agetc37, Emot17, Beh14, Cog9) were removed for low loadings and communalities, following standard EFA guidelines (Costello & Osborne, 2005; Hair et al., 2019).

The scree plot and eigenvalues supported a four-factor solution, with a clear drop after the fourth factor, indicating minimal additional variance from further factors. Analysis of the remaining 33 items showed excellent sampling adequacy (KMO = .952) and a significant Bartlett's Test of Sphericity, χ^2 (528) = 5002.698, $p < .001$ (Kaiser, 1974; Tabachnick & Fidell, 2019). Factor rotation converged in five iterations, producing a stable, simple-structure solution without problematic cross-loadings (see Appendix E).

The final four-factor model explained 61.93% of the total variance, with strong factor loadings (.582–.790) and adequate communalities (.531–.813). All subscales demonstrated high internal consistency, supporting the construct validity and multidimensional structure of the 33-item engagement scale and justifying its use in further reliability testing and confirmatory factor analysis (DeVellis, 2012) (see Table 9).

Table 9

Rotated factor matrix, communalities for engagement profiles (n = 200)

	Factor Loadings				**Communalities**	
Indicators	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Initial**	**Extraction**
COG11	.585				.561	.561
COG7	.696				.676	.677
COG8	.719				.704	.706
COG10	.637				.687	.687
COG4	.598				.566	.583
COG1	.640				.613	.623
COG2	.712				.728	.731
COG3	.666				.588	.594
COG5	.790				.811	.813
COG6	.780				.797	.753
COG12	.652				.708	.726
BEH13		.602			.593	.583
BEH15		.713			.720	.735
BEH18		.708			.670	.652
BEH16		.672			.647	.630
BEH19		.649			.576	.578
BEH21		.710			.645	.636
BEH20		.685			.642	.638
BEH22		.614			.568	.570
BEH23		.628			.592	.581
EMOT24			.645		.678	.682
EMOT26			.724		.750	.737
EMOT25			.744		.731	.749
EMOT27			.751		.717	.707
EMOT28			.764		.724	.723
EMOT31			.725		.709	.711
EMOT30			.689		.645	.641
AGTC32				.589	.524	.531
AGTC33				.662	.610	.622
AGTC36				.737	.620	.651
AGTC34				.657	.557	.531
AGTC35				.582	.560	.562
AGTC38				.591	.632	.599
Cronbach's alpha	.942	.911	.931			
Total Cronbach's alpha	.943					

Cronbach's alpha coefficients indicated high reliability for each subscale and the overall scale, confirming that items retained after EFA form coherent and consistent measures. These results support the stability of the factor structure and the scale's suitability for confirmatory factor analysis and further psychometric evaluation (DeVellis, 2021). A follow-up study with an independent sample was conducted to verify reliability and construct validity.

3.8.4.2. Validity and reliability tests

After exploratory factor analysis (EFA), the factor structure was evaluated, followed by assessments of reliability and construct validity. Internal consistency was tested using an independent sample to provide a less biased estimate (Tavakol & Dennick, 2011). Cronbach's alpha (α) was used to assess reliability, with .70 as the minimum acceptable threshold (Cho & Kim, 2015; Green & Yang, 2015). All scales demonstrated strong to excellent reliability, with α values ranging from .876 to .953.

The Perceived Linguistic Competence Scale (PLCS) and its phonological, lexical, and semantic subscales showed excellent internal consistency (α = .931–.934). The unidimensional Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ) also demonstrated excellent reliability (α = .941). Similarly, the Students' Engagement in Science Learning (SESL) scale, including cognitive, behavioural, emotional, and agentic subscales, yielded high internal consistency (α = .876–.948). These results provide strong evidence of the reliability and methodological rigor of the instruments used to measure the study's key constructs.

To address limitations of Cronbach's alpha, particularly its assumption of tau-equivalence and potential to overestimate reliability, composite reliability (C.R.; Raykov's rho) was estimated within a structural equation modeling framework as a more robust measure (Raykov, 1997). Unlike alpha, C.R. uses standardized factor loadings from confirmatory factor analysis, accounting for differences in item contributions and providing a more construct-sensitive estimate (Collier, 2020). Following established guidelines, a threshold of 0.70 was used to indicate acceptable reliability (Nunnally & Bernstein, 1994).

All constructs demonstrated strong composite reliability, with coefficients ranging from .876 to .965. The perceived linguistic competence scale and its subscales showed excellent reliability (.927 to .964), the perceived textbook linguistic complexity questionnaire yielded a C.R. of .952, and the student engagement in science learning scale and its subscales also demonstrated excellent reliability (.876 to .947), with agentic engagement at the lower bound but still above the acceptable threshold. Consistent with Cronbach's alpha values, these results provide strong evidence for the reliability of the measurement instruments (see Table 10).

Construct validity was initially examined in the pilot study to identify potential measurement issues. A final assessment, including convergent and discriminant validity, was then conducted using the main study data in line with established SEM guidelines (Byrne, 2016; Collier, 2020; Hair et al., 2014; Kline, 2023). Using the pilot data, construct validity and the psychometric adequacy of the measurement models were evaluated through convergent and discriminant validity.

Convergent validity

While confirmatory factor analysis (CFA) provides initial evidence through model fit and factor loadings, it does not by itself establish convergent or discriminant validity (Collier, 2020). Following Collier (2020), convergent validity was assessed using Average Variance Extracted (AVE), with a threshold of $\geq .50$ indicating that a construct explains at least half of the variance in its indicators. Discriminant validity was evaluated by confirming that each construct's AVE exceeded its squared inter-construct correlations, confirming that constructs share more variance with their own indicators than with others (Henseler et al., 2015)

Construct validity for the measurement models, including perceived linguistic competence, perceived textbook linguistic complexity, and engagement profiles, was first examined in the pilot study and then confirmed in the main study using CFA in AMOS. All constructs exceeded the AVE threshold, including phonological competence (.639), lexical competence (.730), and semantic competence (.748) under perceived linguistic competence, perceived textbook linguistic complexity (.669), and engagement dimensions, namely cognitive (.542), behavioural (.580), emotional (.624), and agentic (.683), confirming convergent validity (Hair et al., 2014). Discriminant validity was also supported, as all squared inter-construct correlations were lower than their corresponding AVEs (see Table 11 & 12).

A second-order CFA assessed the hierarchical structure of perceived linguistic competence and engagement profiles, alongside a unidimensional model of perceived textbook linguistic complexity. Perceived linguistic competence was specified as a higher-order construct reflected by PPLC, PLLC, and PSLC. Standardized loadings were ranged from 0.580 to .891 for PPLC, .829 to .898 for PLLC, and .806 to .933 for PSLC, indicating strong item contributions. Convergent validity was supported, with AVE values of 0.696 (PPLC), .750 (PLLC), and .768 (PSLC), demonstrated high internal consistency.

The second-order factor representing overall perceived linguistic competence loaded significantly onto its first-order dimensions, with an AVE of .563 and high composite reliability (C.R. = .933–.944), supporting the hierarchical model. Perceived textbook linguistic complexity (PTLC) was modeled as a unidimensional construct with nine indicators, showing standardized loadings of .672 to .908, strong convergent validity (AVE = .669), and high internal consistency (C.R. = .948), confirming it is reliably represented as a single-dimensional construct within the measurement model.

Engagement was modeled as a second-order construct comprising cognitive (COG), behavioural (BEH), emotional (EMOT), and agentic (AGNT) dimensions. Second-order loadings ranged from .782 to .851, with substantial first-order indicator loadings (COG: .685 to .894; BEH: .708 to .809; EMOT: .774 to .861; AGNT: .691 to .782). AVE values exceeded

.50 for all first-order factors (.542 to .683) and for the second-order construct (.668), with high composite reliability (C.R. = .876 to .947), supporting convergent validity and internal consistency. CFA results confirmed that all first-order, second-order, and unidimensional constructs demonstrated strong reliability and validity, making them suitable for structural analyses.

Table 10

Reliability and Validity Indices of the Study Variables (n = 200)

Constructs	No. of Indicators	Loadings	AVE	α	CR
PPLC	7	.722-.841	.639	.931	.933
PLLC	9	.750-.832	.730	.934	.936
PSLC	5	.781-851	.748	.932	.935
PLC (Second-order)	3	.695-.768	.563	.943	.944
PTLC	9	.672-.908	.669	.941	.948
COG	11	.585-.790	.542	.948	.947
BEH	9	.602-.710	.580	.925	.925
EMOT	7	.645-.764	.624	.937	.937
AGNT	6	.591-.737	.683	.876	.876
EPs (Second-order)	4	.782-.851	.668	.953	.955

Note: AVE, average variance extracted; α, alpha value; CR, composite reliability; PPLC, perceived phonological linguistic competence; PLLC, perceived lexical linguistic competence; PSLC, perceived semantic linguistic competence; PLC, perceived linguistic competence; COG, cognitive engagement; EMO, emotional engagement; BEH, behavioral engagement; AGNT, agentic engagement, and EPs, engagement profiles

Discriminant validity assessment

Discriminant validity was confirmed by HTMT values below .85, indicators loading highest on their intended constructs, and satisfaction of the Fornell–Larcker criterion, whereby each construct's AVE (or its square root) exceeded its correlations with other constructs (Hair, 2019; Fornell & Larcker, 1981).

For the perceived linguistic competence (PLC) constructs, AVE values ranged from .639 to .748. Inter-construct correlations were moderate (.579 to .633) and significant at the 0.01 level. Each construct's AVE exceeded its squared correlations with the others, indicating that perceived phonological (PPLC), lexical (PLLC), and semantic (PSLC) competence each capture a distinct aspect of perceived linguistic competence (see Table 11).

Table 11

Discriminant validity assessment for constructs of PLC (n = 200)

Perceived Linguistic Competence	AVE	Correlation between Constructs		
		(1)	(2)	(3)
(1) PPLC	.639	1		
(2) PLLC	.730	.528**	1	
(3) PSLC	.748	.559**	.638**	1

Note. **. Correlation is significant at the 0.01 level (2-tailed); AVE (Average Variance Extracted); PPLC (perceived phonological linguistic competence); PLLC (perceived lexical linguistic competence); PSLC (perceived semantic linguistic competence)

For the engagement profiles (EPs), AVE values ranged from .542 to .683, with moderate inter-construct correlations (.476–.574), all significant at the .01 level. Each dimension, cognitive (COG), behavioral (BEH), emotional (EMOT), and agentic (AGNT), had an AVE exceeding its squared correlations with the other dimensions, supporting discriminant validity (see Table 12).

Table 12

Discriminant validity assessment for constructs of EPs (n = 200)

Engagement Profiles	AVE	Correlation between Constructs			
		(1)	(2)	(3)	(4)
(1) COG	.542	1			
(2) BEH	.580	.534**	1		
(3) EMOT	.624	.544**	.554**	1	
(4) AGNT	.683	.471**	.429**	.411**	1

Note. **. Correlation is significant at the 0.01 level (2-tailed); AVE (Average Variance Extracted); COG (cognitive engagement); BEH (behavioural engagement); EMOT (emotional engagement); AGNT (agentic engagement)

3.8.4.3. Reliability for LCJT

Fleiss' Kappa (κ) (Fleiss, 1971) was used to assess inter-rater reliability for the Linguistic Complexity Judgement Task (LCJT), involving 40 students (24 females, 16 males) classifying words as "complex" or "not complex" across four reading texts. Fleiss' Kappa is suitable for measuring agreement among multiple raters assigning categorical labels. Only words with valid judgments from all 40 students were included, leaving 169 lexical items. For each word, the counts of "complex" and "not complex" responses were used to construct the rating matrix for the Fleiss' Kappa calculation.

Fleiss' Kappa ($\kappa = (\bar{P} - \bar{P}e) / (1 - \bar{P}e)$) is a chance-corrected measure of inter-rater agreement, where $\bar{P}$ is the mean observed agreement across raters and items, and $\bar{P}e$ is the mean agreement expected by chance based on category marginals (Fleiss, 1971). The analysis, supplemented by percentage agreement, indicated substantial inter-rater reliability ($\kappa \approx .70$, 95% CI: .65–.70) with an overall agreement of 84.3 %, reflecting high consistency among students in classifying words as "complex" or "not complex" (Fleiss et al., 1979).

A κ value of approximately .70 indicates strong consensus among students, with many items receiving highly consistent ratings (e.g., 38–40 students selecting the same category). This pattern suggests a shared understanding of word difficulty and stable responses across items. The substantial agreement also supports the LCJT as a reliable assessment tool, capturing consistent judgments of lexical complexity rather than highly variable responses.

The Linguistic Complexity Judgement Task (LCJT) is methodologically appropriate for validating construct measures, as construct validity requires that a tool reflects how users perceive the underlying concept (Cronbach, 1951; Messick, 1995). Word-level judgment tasks are commonly used in applied linguistics and psycholinguistics to assess lexical complexity (Gwet, 2021; McKercher et al., 2011). In this study, the LCJT captured learners' judgments of words in authentic instructional texts and compared them with objective phonological, lexical, and semantic indices, providing context-based evidence of construct validity.

3.8.4.4. Confirmatory factor analysis (CFA)

Confirmatory Factor Analysis (CFA) was conducted to confirm the factor structure identified through EFA and assess model fit. A second pilot study involved 200 seventh-grade students who completed the 21-item perceived linguistic competence scale, 33-item engagement scale, and 9-item perceived textbook linguistic complexity scale, meeting recommended sample size requirements for CFA (DeVellis, 2021; Hair et al., 2014; Kline, 2023).

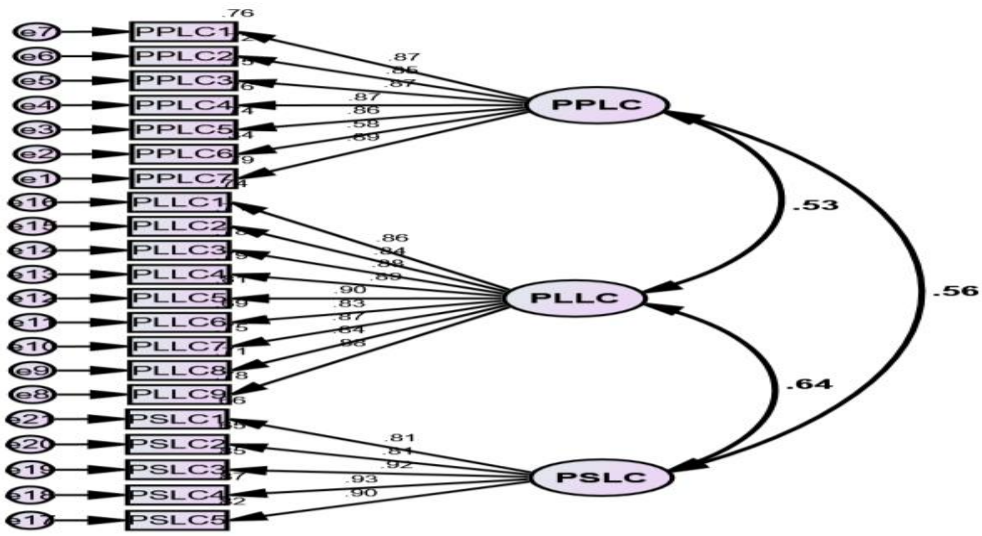
Construct validity was assessed using CFA. First-order CFA was applied to the unidimensional Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ), and second-order CFA to the multidimensional Perceived Linguistic Competence Scale (PLCS) and Students' Engagement in Science Learning (SESL) scale. Model fit was evaluated using Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) $\leq .08$, Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) $\geq .90$, and chi-square/df ratio < 5 indicating acceptable model fit (Brown, 2015; Byrne, 2016; Collier, 2020; Kline, 2023).

CFA for perceived linguistic competence constructs

A confirmatory factor analysis (CFA) was conducted for the Perceived Linguistic Competence Scale (PLCS), and the results showed a good model fit. The indices, CMIN/DF $<$ 3.0, CFI = .961, TLI = .953, SRMR = .043, and RMSEA = .041, all met recommended thresholds, supporting the adequacy of the model. Figure 4 presents the CFA model with three latent constructs, PPLC, PLLC, and PSLC, each measured by multiple observed indicators. The factor loadings ranged from .589 to .931, indicating that the items adequately and reliably reflected their respective constructs (see Figure 4).

Figure 4

The three-factor perceived linguistic competence measurement model (n =200)

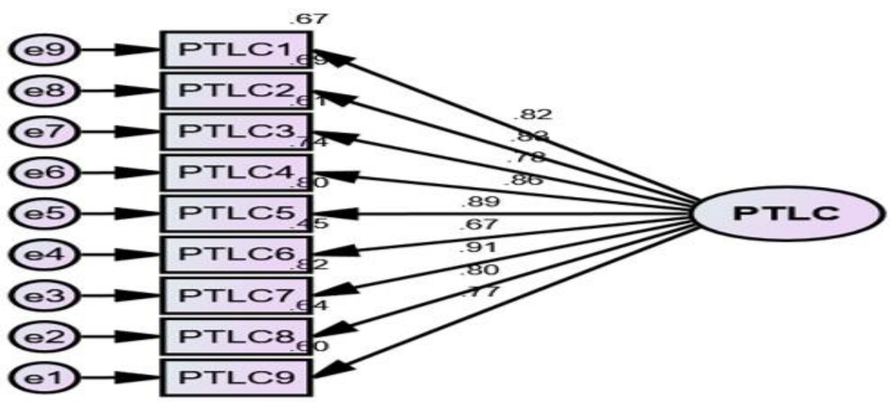


CFA for textbook linguistic complexity construct

Confirmatory factor analysis (CFA) of the Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ) indicated an acceptable model fit. The indices, CMIN/DF = 1.791, CFI = .946, TLI = .921, SRMR = .056, and RMSEA = .055, all met recommended thresholds, supporting the proposed factor structure and the factorial validity of the PTLCQ measurement model. Figure 5 shows the confirmatory factor analysis result of the construct with high factor loadings (0.58–0.93), indicating that the items reliably represent their respective constructs.

Figure 5

The one-factor textbook linguistic complexity measurement model (n =200)

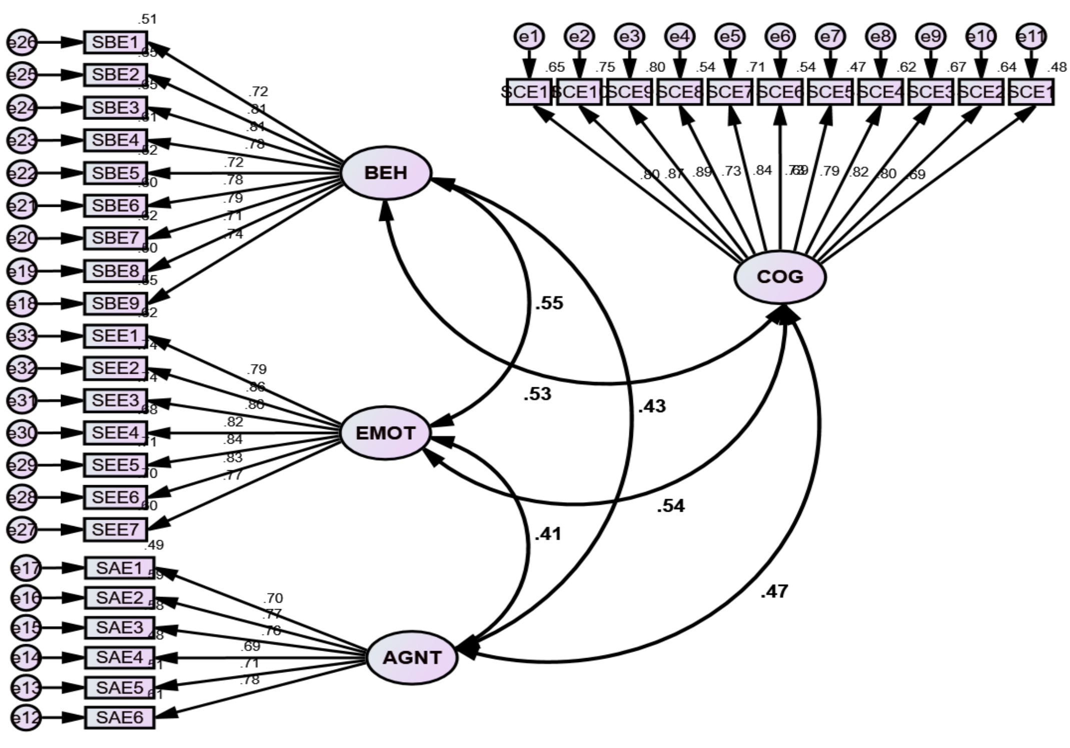


CFA for engagement profiles constructs

Confirmatory factor analysis (CFA) of the Student Engagement in Language Study Scale (SELS) showed acceptable model fit: $\chi^2/df = 1.701$, Comparative Fit Index (CFI) = .941, Tucker–Lewis Index (TLI) = .932 (> .90), Standardized Root Mean Square Residual (SRMR) = .051, and Root Mean Square Error of Approximation (RMSEA) = .062 (see Figure 6). These results support the adequacy of the SELS measurement model and confirm that its indicators reliably represent the engagement construct.

Figure 6

The four-factor engagement profiles measurement model (n =200)



3.8.5. The model fit indices for each scale

As reported in Table 13, the CFA results demonstrated acceptable to excellent fit indices across all instruments, supporting the validity of the measurement structure and its suitability for subsequent structural analyses.

Table 13

Model fit indices of CFA results for each scale (n = 200)

Measurements	Model fit indices				
	CMIN/DF	CFI	TLI	SRMR	RMSEA
PLCS	1.680	.961	.953	.043	.041
PTLCQ	1.791	.946	.921	.056	.055
SELS	1.701	.941	.932	.051	.052

Note. PLCS (perceived linguistic competence scale); PTLCQ (perceived textbook linguistic complexity questionnaire); and SELS (students' engagement in learning science) scale

3.8.5.1. Factor loadings

Factor loadings represent the strength of the relationship between observed indicators and their latent constructs (Collier, 2020). Loadings of .70 or higher are preferred, indicating strong item reliability and substantial shared variance (Hair et al., 2014). Items with loadings between .50 and .69 may be retained in pilot studies if theoretically justified or contributing meaningful content, provided overall model fit and construct validity remain acceptable (Collier, 2020; Hair et al., 2014; Kline, 2023).

In the pilot study, standardized factor loadings ranged from .580 to .933, indicating moderate to strong relationships between items and their latent constructs. PTLCQ items loaded strongly (.672–.908), while PLCS dimensions showed moderate to high loadings: PPLC (.580–.891), PLLC (.829–.898), and PSLC (.806–.933). Engagement profile dimensions also demonstrated acceptable loadings, including cognitive (.685–.894), behavioural (.708–.809), emotional (0.774–0.861), and agentic engagement (.691–.774).

All constructs met preliminary validity criteria, with AVE values above .50 and composite reliability (CR) ranging from .876 to .964. Although a few items in perceived phonological competence and cognitive engagement had lower loadings, they were retained because such values are acceptable in pilot studies when most items load strongly and AVE exceeds .50, and because they may reflect unique aspects of the constructs (Collier, 2020). Overall, the findings suggest that the scales are reliable and suitable for the main study.

3.8.5.2. Correlation Analysis of Pilot Study Data

Following reliability, construct validity, and factor analyses, correlation analysis of the pilot data examined relationships among study variables. Results showed significant positive correlations between perceived linguistic competence, engagement profiles, and science achievement, while perceived textbook linguistic complexity was significantly negatively correlated with the other variables at $p < .01$ (see Table 14).

Table 14

Pearson Correlations among Study Variables (n = 200)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Sci Ach	1								
(2) PPLC	.390**	1							
(3) PLLC	.441**	.388**	1						
(4) PSLC	.422**	.379**	.433**	1					
(5) PTLC	-.582**	-.481**	-.464**	-.570**	1				
(6) COG	.514**	.428**	.597**	.550**	-.541**	1			
(7) BEH	.564**	.385**	.463**	.422**	-.518**	.434**	1		
(8) EMOT	.437**	.361**	.249**	.391**	-.268**	.344**	.474**	1	
(9) AGNT	.350**	.279**	.424**	.311**	-.535**	.376**	.439**	.311**	1

Note. **. Correlation is significant at the 0.01 level (2-tailed).

3.8.5.3. Testing common method bias

Since the study relied on self-reported measures, common method bias (CMB) was assessed before structural equation modeling (Podsakoff et al., 2003). Harman's single-factor test, forcing all 63 items onto one unrotated factor, accounted for 25% of the variance, well below the 50% threshold, indicating minimal CMB. Additionally, a common method factor approach compared CFA models with and without a method factor ($\chi^2 = 321.051$ vs. $\chi^2 = 317.862$; $\Delta\chi^2 = 3.189$, 1 df < 3.84, $p = .05$). These results indicate that common method bias was not a concern in this study.

3.8.5.4. Testing measurement invariance of constructs

Measurement invariance was established across gender, supporting valid multi-group SEM comparisons. Table 4 shows that configural invariance was confirmed by consistent factor structures, metric invariance by p-values > .05, and scalar invariance by non-significant differences in means and variances (Collier, 2020). Fit indices met recommended thresholds, and ΔCFI ≤ 0.01 confirmed invariance for engagement profiles, linguistic competence, and perceived linguistic complexity, indicating equivalent loadings and intercepts (see Table 15).

Table 15

Measurement invariance results across genders (n = 200)

Constructs	Model	Model Fit Tests						Decision
		X^2/df	GFI	CFI	TLI	RMSEA	SRMR	
EPs	Configural	1.67	.90	.96	.95	.04	.05	Accepted
	Metric	1.64	.92	.96	.96	.04	.05	Accepted
	Scalar	1.69	.90	.95	.95	.04	.07	Accepted
PLC	Configural	1.69	.89	.97	.97	.04	.03	Accepted
	Metric	1.66	.92	.97	.97	.04	.04	Accepted
	Scalar	1.75	.89	.97	.97	.07	.07	Accepted
PTLC	Configural	1.68	.91	.97	.93	.05	.06	Accepted
	Metric	1.63	.93	.96	.96	.05	.05	Accepted
	Scalar	1.173	.92	.96	.96	.06	.07	Accepted

Note. EPs (engagement profiles), PLLC (perceived linguistic competence), PTLC (perceived linguistic complexity); χ^2/df (Chi-square divided by degrees of freedom, or normed Chi-square), GFI (Goodness-of-Fit Index), CFI (Comparative Fit Index), TLI (Tucker–Lewis Index), RMSEA (Root Mean Square Error of Approximation), and SRMR (Standardized Root Mean Square Residual)

3.9. Data Analysis Procedures

Following established guidelines for cross-cultural translation and validation (Beaton et al., 2000), the Amharic version of the questionnaires was pretested with 30 students to assess clarity and comprehensibility, with all participants reporting no difficulties, confirming its suitability for the pilot and main studies.

Data collection was conducted in two phases. In the first phase, questionnaires were administered to 523 seventh-grade students to investigate the effects of perceived linguistic competence and perceived textbook linguistic complexity on science achievement via engagement profiles. Questionnaires were completed individually under conditions ensuring response confidentiality, with an estimated completion time of 45–50 minutes. Administration and collection were carried out by the researcher and one PhD student in Educational Psychology, and it took over a two-weeks, from March 26 to April 12, 2024.

In the second phase, 210 students completed a Linguistic Complexity Judgment Task (LCJT), identifying phonologically, lexically, and semantically complex words in selected Grade 7 science textbook texts. The task, completed individually in about 80 minutes, assessed perceived textbook linguistic complexity and its relationship with engagement profiles and science achievement. Data were collected from April 22–26, 2024.

3.10. Preliminary tasks of data analysis

Before conducting formal statistical modeling or hypothesis testing, preliminary procedures were conducted to ensure data integrity and suitability, and key statistical assumptions were systematically evaluated to prevent biased estimates or distorted model interpretation (Kline, 2023).

3.10.1. Data coding, screening, and missing value

The dataset was subjected to systematic coding, screening, and validation procedures to ensure accuracy and analytical suitability. Of 523 questionnaires collected, 23 were excluded for incompleteness, yielding a final sample of 500 participants. Data were analyzed using IBM SPSS Statistics 24 and AMOS 23.

Responses for perceived linguistic competence, perceived textbook linguistic complexity, and engagement profiles were entered as provided. Positive items were coded directly, while negatively worded items, such as PPLC6, PPLC7, PLLC2, PLLC3, PLLC4, PLLC6, PLLC9, PSLC3, PSLC5 for perceived linguistic competence, and COG8, BEH4 for engagement profiles were reverse-scored, maintaining the 1–5 scale and directional consistency. Negative items in perceived textbook linguistic complexity were not reverse-scored, in line with the construct’s conceptual structure and the objectives of the study.

Frequency distributions and descriptive statistics confirmed all responses were within the 1–5 range, with no missing data. Assumptions for structural equation modeling were then assessed, including univariate distributions and multivariate suitability, confirming the data met all criteria for SEM analyses.

3.10.2. Assumption testing for the main analysis

Before the main analysis, the data were screened for SEM and multiple regression assumptions, including normality, linearity, data completeness, multicollinearity, sample adequacy, and unidimensionality (Collier, 2020; Hair et al., 2014; Kline, 2023; Tabachnick & Fidell, 2001). Univariate normality was supported by skewness and kurtosis values within ±2, while Mardia's skewness and kurtosis critical ratios below 5 indicated multivariate normality, justifying the use of maximum likelihood estimation (Byrne, 2016; Hair et al., 2019; Kline, 2023).

Table 16

Mardia's multivariate normality skewness and kurtosis coefficients (n = 500)

Variable	Min	Max	Skewness	C.R.	Kurtosis	C.R.
PPLC	1.222	4.889	-.154	-.401	-.351	-1.166
PLLC	1.000	5.000	-.013	-.123	-.256	-1.733
PSLC	1.222	5.000	-.037	-.338	-.594	-1.276
PTLC	1.143	5.000	-.036	-.331	-.350	-1.164
COG	1.000	5.000	.283	.582	-.113	-2.020
BEH	1.000	5.000	.404	.691	-.295	-1.913
EMOT	1.111	5.000	.327	.983	-.228	-1.606
AGNT	1.091	4.909	.495	.519	-.165	-1.319
Sci Ach	41.000	96.000	.556	.071	-.451	-2.059
Multivariate					5.125	4.731

Note. PPLC (perceived phonological linguistic competence); PLLC (perceived lexical linguistic competence); PSLC (perceived semantic linguistic competence); PTLC (perceived textbook linguistic complexity); COG (cognitive engagement); BEH (behavioural engagement); EMOT (emotional engagement); AGNT (agentic engagement); and Sci Ach (science achievement)

Multicollinearity among predictors was assessed using bivariate correlations, tolerance, and VIF. Correlations were below .85, tolerance exceeded .20, and VIF values were well under

5, indicating no problematic multicollinearity and confirming predictors were sufficiently distinct for inclusion in the path model (Hair et al., 2019; Kline, 2023) (see Tables 17 & 18).

Table 17

Assessment of Multicollinearity Using Pearson correlation (n = 500)

Constructs	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) PPLC	1							
(2) PLLC	.392**	1						
(3) PSLC	.380**	.435**	1					
(4) PTLC	-.379**	-.468**	-.472**	1				
(5) COG	.331**	.562**	.489**	-.412**	1			
(6) BEH	.343**	.459**	.426**	-.381**	.435**	1		
(7) EMOT	.360**	.351**	.419**	-.367**	.446**	.502**	1	
(8) AGNT	.322**	.433**	.422**	-.427**	.375**	.437**	.401**	1

Note. PPLC (perceived phonological linguistic competence); PLLC (perceived lexical linguistic competence); PSLC (perceived semantic linguistic competence); PTLC (perceived textbook linguistic complexity); COG (cognitive engagement); BEH (behavioural engagement); EMOT (emotional engagement); and AGNT (agentic engagement)

Table 18

Multicollinearity using tolerance and variance inflation factor (VIF) (n = 500)

Variables	Tolerance	Variance Inflation Factor (VIF)
PPLC	.670	1.476
PLLC	.761	1.352
PSLC	.549	1.896
PTLC	.687	1.363
COG	.597	1.800
BEH	.628	1.894
EMOT	.576	1.884
AGNT	.639	1.497

Note. PPLC (perceived phonological linguistic competence); PLLC (perceived lexical linguistic competence); PSLC (perceived semantic linguistic competence); PTLC (perceived textbook linguistic complexity); COG (cognitive engagement); BEH (behavioural engagement); EMOT (emotional engagement); AGNT (agentic engagement); Sci Ach (science achievement), and dependent variable is Science Achievement

Linearity, a key SEM assumption, was evaluated via scatterplots and residual plots, showing approximately linear relationships without systematic curvature or heteroscedasticity (Byrne, 2016; Kline, 2023). Missing data were minimal after screening, and Full Information

Maximum Likelihood (FIML) was used, producing unbiased estimates under MCAR conditions while utilizing all available data (Enders, 2010; Schafer & Graham, 2002).

Adequate sample size is crucial for stable SEM estimates and sufficient power, with guidelines recommending at least 200 cases or 10 participants per parameter (Hair et al., 2014; Kline, 2023). Two datasets were evaluated; 500 participants for examining perceived linguistic competence and textbook linguistic complexity on science achievement via engagement, and 193 participants for assessing linguistic complexity in texts and its relation to engagement and achievement. Both samples exceeded recommended thresholds, ensuring sufficient analytical power (Wolf et al., 2013).

Construct unidimensionality was confirmed using CFA, with all standardized loadings > 0.50, statistically significant, and model fit indices (CMIN/DF, CFI, TLI, RMSEA, SRMR) within acceptable thresholds, supporting the measurement models (Hair et al., 2014). Assumptions for multiple regression, linearity, normality and homoscedasticity of residuals, independence of observations, and absence of multicollinearity, were all satisfied, with no influential outliers detected, confirming the data's suitability for valid regression analysis.

Assumption testing for text analysis tools, Ure (1971), Halliday (2009), TAALES, and TAACO, evaluated lexical density, sophistication, and cohesion against external indicators like reader comprehension, readability, and expert ratings, confirming their validity. The datasets met all relevant assumptions, showing normality, linearity, independence, minimal missing data, adequate sample size, and unidimensional constructs, supporting the validity, reliability, and interpretability of subsequent SEM and text complexity analyses.

3.10.3. Descriptive Statistics

Descriptive statistics for perceived phonological, lexical, semantic, and textbook linguistic competence, and for dimensions of engagement profiles including cognitive, behavioural, emotional, and agentic engagement, as well as for science achievement are presented in Table 29. All variables demonstrated approximately normal distributions, with skewness ranging from −0.923 to 0.887 and kurtosis from −0.566 to −0.216, and means and standard deviations indicating moderate variability.

Table 19

Descriptive Statistics for the study variables (n = 500)

Variables	Min.	Max.	Mean	Std. Dev	Skewness	Kurtosis
PPLC	8	35	20.76	8.048	.701	-.484
PLLC	10	44	26.92	10.629	.856	-.564
PSLC	5	25	16.21	5.585	-.923	-.382
PTLC	11	44	29.32	9.660	-.745	-.368
COG	12	54	30.59	11.104	.802	-.265
BEH	11	44	27.24	9.279	.683	-.374
EMOT	7	34	19.65	8.234	.739	-.258
AGNT	7	30	17.05	6.425	.537	-.216
Sci Ach	41	96	62.51	11.962	.887	-.544

Note. Max = Maximum; Min = Minimum; Std. Dev = Standard Deviation; PPLC = Perceived Phonological Linguistic Competence; PLLC = Perceived Lexical Linguistic Competence; PSLC = Perceived Semantic Linguistic Competence; PTLC = Perceived Textbook Linguistic Competence; COG = Cognitive Engagement; BEH = Behavioural Engagement; EMOT = Emotional Engagement; AGNT = Agentic Engagement; Sci Ach = Science Achievement.

3.10.4. Measurement model validation using confirmatory factor analysis

Before hypothesis testing, the measurement scales were evaluated in AMOS using confirmatory factor analysis following SEM guidelines (Collier, 2020; Hair et al., 2014). Convergent validity was supported by acceptable factor loadings, composite reliability, and AVE values above 0.50, including AVE = 0.57 for perceived textbook linguistic complexity and 0.61–0.76 for first-order engagement profiles, with a second-order AVE of 0.66. Discriminant validity was confirmed using the Fornell–Larcker criterion, HTMT (< 0.85), and Collier's criterion, as AVE square roots exceeded inter-construct correlations and squared correlations remained below corresponding AVE values.

Reliability was confirmed with Cronbach's alpha and composite reliability, all above the 0.70 threshold (Hair et al., 2019), and all factor loadings were significant ($p < .01$) and > .60. Model fit met recommended criteria (CMIN/DF < 3, TLI/CFI ≥ 0.90, RMSEA < 0.08, SRMR < 0.05) (Dash & Paul, 2021). Perceived linguistic competence and engagement profiles were multidimensional, while perceived textbook linguistic complexity was unidimensional, with seven first-order constructs and one unidimensional construct (63 items) included; these validated constructs were then used in the SEM to test the hypothesised relationships.

Assessing model fit at both first- and second-order levels is essential for construct validity (Kline, 2023). First-order validity confirms that items represent their constructs, while second-order validity ensures higher-order constructs appropriately reflect their dimensions (Raza et al., 2020). Meeting fit criteria at both levels indicates reliable measurement and supports hierarchical modelling (Goretzko et al., 2024; Lambert & Newman, 2023; Sathyanarayana & Mohanasundaram, 2024).

CFA indicated good to excellent model fit across all analyses (see Table 20). First-order models fit well for perceived linguistic competence (CMIN/DF = 1.659, CFI = 0.962, RMSEA = 0.038) and engagement profiles (CMIN/DF = 1.690, CFI = 0.939, RMSEA = 0.059). Second-order models also showed good fit for perceived linguistic competence (CMIN/DF = 1.570, CFI = 0.964, RMSEA = 0.037) and engagement profiles (CMIN/DF = 1.684, CFI = 0.941, RMSEA = 0.057). Textbook linguistic complexity demonstrated strong unidimensional fit (CMIN/DF = 1.528, CFI = 0.974, RMSEA = 0.051), confirming measurement adequacy.

Table 20

Confirmatory factor analysis (CFA) fit indices for first- and second-order measurement models

Construct	Level	CMIN/DF	CFI	TLI	RMSEA	SRMR
PLC	First-order	1.659	.962	.958	.038	.039
	Second-order	1.570	.964	.959	.037	.038
EPs	First-order	1.690	.939	.934	.059	.053
	Second-order	1.684	.941	.936	.057	.052
PTLC	Unidimensional	1.528	.974	.964	.051	.047

Note. EPs (engagement profiles), PLLC (perceived linguistic competence), PTLC (perceived linguistic complexity); χ^2/df (Chi-square divided by degrees of freedom, or normed Chi-square), GFI (Goodness-of-Fit Index), CFI (Comparative Fit Index), TLI (Tucker–Lewis Index), RMSEA (Root Mean Square Error of Approximation), and SRMR (Standardized Root Mean Square Residual)

3.10.5. Structural model analysis and path estimation

Structural Equation Modeling (SEM) was used to examine the direct and indirect effects of perceived linguistic competence and textbook linguistic complexity on science achievement, with cognitive, behavioural, emotional, and agentic engagement as mediators. Path analysis estimated these effects using standardized beta coefficients (β), and model fit was assessed. As shown in Table 21, the model fit the data well, and significance was evaluated with bootstrapped 95% confidence intervals.

Table 21

Goodness-of-Fit Indices of the Full Structural Model (n = 500)

Model Fit Indices							
CMIN/DF	CFI	GFI	TLI	SRMR	RMSEA	AGFI	NFI
1.739	.956	.921	.944	.073	.041	.903	.911

The structural model showed a good fit to the data. The relative chi-square (CMIN/DF) was 1.941, indicating acceptable fit. Other indices also supported this, including CFI = .956, GFI = .921, TLI = .944, SRMR = .073, RMSEA = .041, AGFI = .901, and NFI = .911, all meeting or exceeding conventional thresholds for acceptable model fit (Collier, 2020).

3.11. Data Analysis Methods

Prior to the main data analyses, data were cleaned by screening questionnaires for completeness and irregular responses. Statistical assumptions, including missing data, outliers, normality, linearity, multicollinearity, and homogeneity of variance, were then tested to ensure suitability. Analyses were conducted using SPSS 25, AMOS 23, and linguistic tools TAALES and TAACO. AMOS, a structural equation modeling software, extends multivariate techniques like regression, factor analysis, correlation, and ANOVA, and is considered more user-friendly than LISREL, Mplus, or EQS (Dash & Paul, 2021). TAALES evaluates lexical sophistication, while TAACO assesses text cohesion and semantic sophistication.

The analysis included descriptive statistics (means and standard deviations) to summarize participants' demographics and levels of perceived linguistic competence, textbook linguistic complexity, and engagement profiles. Pearson correlations were used to assess the direction and strength of relationships among variables, forming a basis for subsequent SEM. Multiple regressions was also conducted to examine the predictive effects of the independent variables on the outcome variable.

Univariate and multivariate outliers were identified using Mahalanobis distance and p-values in AMOS. Univariate normality was assessed via skewness (< ±2) and kurtosis (< ±7) (Byrne, 2016), while multivariate normality was evaluated using Mardia's normalized kurtosis, with total kurtosis < 10 and critical ratio < 5 considered acceptable (Bentler, 2006). Structural equation modeling (SEM) was then applied to examine the hypothesized relationships and to assess the mediating role of engagement dimensions, cognitive, behavioural, emotional, and agentic, between perceived linguistic competence, perceived textbook linguistic complexity, and science achievement among seventh-grade students.

Model fit was evaluated using RMSEA (≤ .08), TLI and CFI (≥ .90), and CMIN/DF (< .50) to indicate acceptable or good fit (Collier, 2020; Kline, 2023). Indirect effects were tested with 5,000 bootstrap samples and bias-corrected 95% confidence intervals, with significance indicated when the CI did not include zero. Two-tailed p-values < .05 denoted statistical significance, and standardized coefficients were interpreted as effect sizes: .01 (small), .09 (medium), and .25 (large) (Preacher & Kelley, 2011).

Data from the Complexity Judgment Task and content analysis were analyzed using descriptive and inferential statistics, following established quantitative approaches to textbook linguistic complexity. Descriptive analyses summarized the frequency and percentage of phonological, lexical, and semantic complexity features in the texts. Lexical density, reflecting informational load, was calculated using Ure's (1971) method as the proportion of content words to total words, enabling systematic comparison of informational density across texts.

Lexical sophistication was assessed using a TAALES-based approach, operationalizing vocabulary difficulty through learner-judged thresholds of pronunciation difficulty and word familiarity, consistent with TAALES's focus on frequency and lexical accessibility. Textual abstractness and cohesion were measured using Type–Token Ratio (TTR) via TAACO, with higher TTR values indicating lower cohesion and greater abstractness.

To extend beyond descriptive analysis, correlational analyses examined relationships among textbook linguistic complexity measures, engagement profiles, and science achievement, estimating the relative contributions of lexical density, lexical sophistication, textual cohesion, and engagement within a single predictive model. These procedures are appropriate for content analysis and educational research, allowing systematic quantification of linguistic features and evaluation of relationships and combined effects among variables (Boateng et al., 2018; Drisko & Maschi, 2016; Schram, 2014).

3.12. Ethical Issues

In the present study, the researchers followed a strong ethical protocol, approved by the Institutional Research Review Committee (IRRC) at the College of Education, Bahir Dar University (Approval No. 001955, 23/09/2024) to ensure compliance with ethical standards for research involving human participants. Permission was then obtained from the school directors, in each school, to conduct the study and access students' semester science score from the roster.

After permission was obtained, students were briefly informed in Amharic about the study during class, invited to participate and asked to provide informed consent, which included their agreement to participate and to allow access to their semester science achievement score from the roster. All students voluntarily agreed to participate, and no one was forced to participate in the study. They were assured that their responses would remain anonymous and confidential.

Participants were selected transparently and equitably based on predefined eligibility criteria for middle school students, with all treated respectfully and impartially. Data confidentiality was maintained through secure, encrypted storage and removal of personal identifiers. Findings, including expected and unexpected results, were reported transparently, and all secondary sources and adapted instruments were properly acknowledged. The study adhered to Bahir Dar University's research guidelines, ensuring ethical, clear, and transparent practices.

CHAPTER FOUR

RESULTS

4. Introduction

This section presents the study results in two sections. The first section presents the result of textbook linguistic complexity using students' complexity judgments alongside automated analyses with TAALES, TAACO, and related indices, capturing both learner-perceived and computationally measured features of seventh-grade science texts. The second section presents the result of how perceived linguistic competence and textbook complexity affect science achievement through engagement profiles, using multivariate modeling to assess direct and indirect effects and the mediating role of engagement dimensions. Analyses combined descriptive and inferential statistics with LCJT, computational linguistic tools, SPSS, and AMOS, with significance evaluated at the .05 level.

4.1. Linguistic complexity of reading texts in the science textbook

This section reports the results of the textbook linguistic complexity analysis. Complexity was examined using four complementary frameworks: a learner-based Linguistic Complexity Judgment Task (LCJT), Systemic Functional Linguistics (Halliday, 2009; Ure, 1971), lexical sophistication measures from TAALES, and cohesion measures from TAACO (Crossley et al., 2023). This approach combined learner judgments with computational indicators of lexical and semantic complexity. TAALES assessed lexical sophistication (e.g., word frequency and range), while TAACO measured cohesion through lexical overlap, semantic similarity, and connectives, providing triangulated evidence of complexity.

4.1.1. Linguistic complexity judgment task

In the present study, a word was complex if at least 50% of students (≥97 of 193) identifies it complex in any dimension. A more conservative threshold of 40% (≥77 students), commonly used in disciplinary reading text, for example in science subjects, produced similar results. Words identified as complex by 70% or more (≥136 students) were classified as highly complex. Since higher-threshold words are included in lower-threshold groups, the subsets are nested. Reported percentages indicate the proportion of words meeting the 40%, 50%, or 70% criterion across all texts.

Figure 7

Word-level linguistic complexity across four Grade 7 general science reading texts, showing the number of words identified as complex by at least 40%, 50%, and 70% of students (n = 193).

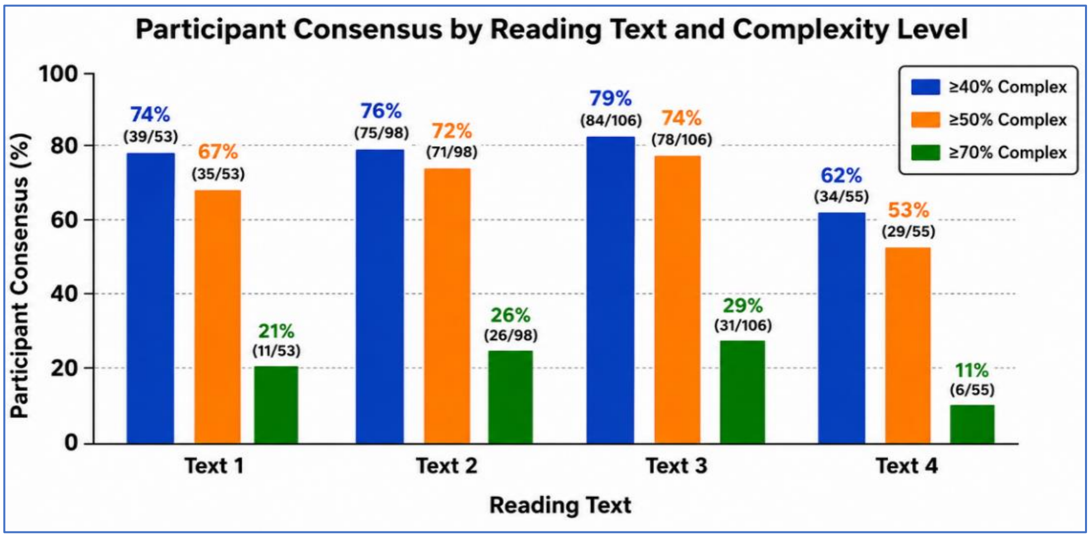


Figure 7 indicates that, irrespective of variations in text length, word count, or structural composition, the linguistic features of the reading passages are consistently perceived as complex by students. Across all four texts, a substantial proportion of respondents identified at least 40% and 50% of the words as complex in each reading texts, with these figures remaining notably high even as textual characteristics differ. A meaningful segment of participants still reports considerable complexity.

4.1.2. Word complexity in science reading texts

Students most often judged words as "complex" when they were hard to pronounce, unfamiliar, technical, or abstract, requiring higher-level thinking. Across the four texts, 312 unique words were analysed in which 96 (31.5%) were identified as complex by over 70% of students, and 214 (68.5%) by over 50%, based on phonological, lexical, or semantic characteristics. Table 23 lists sample words labelled as complex, with student agreement ranging from 73% to 99.6%.

Table 22

Frequency of top Words identified complex across science reading texts (> 73 %)

Word	Percentage of students labelled it as complex (%)	Word	Percentage of students labelled it as complex (%)	Word	Percentage of students labelled it as complex (%)
Giardia	99.64%	Amoeba	95.71%	Moist	83.06%
Chlamydomonas	99.48%	Exerts	95.69%	Reaction	81.99%
Phloem	99.36%	Excretion	95.69%	Newton’s	80.32%
Euglena	99.26%	Aquatic	94.86%	Coordination	78.84%
Pseudopodia	99.06%	Algae	94.86%	Ground	78.39%
Leishmania	98.96%	Vascular	94.64%	Occur	78.39%
Flagella	98.82%	Protozoa	94.60%	Stem	78.23%
Mitochondria	98.73%	Photosynthesize	93.53%	Noted	76.21%
Xylem	98.61%	Digestion	93.53%	Application	76.19%
Cilia	98.41%	Dwelling	93.23%	Leaf-like	76.10%
Paramecium	98.41%	Multicellular	92.92%	Action	75.66%
Pteridophytes	97.94%	Magnitude	92.90%	Numerous	75.66%
Hornworts	97.94%	Single-celled	92.87%	Pairs	75.66%
Frond	97.94%	Unicellular	92.87%	Root-like	74.96%
Eukaryotic	97.89%	Colonial	90.83%	Leaves	74.62%
Protista	97.89%	Microscopic	88.68%	Forward	74.23%
Organelles	96.82%	Diverse	85.65%	Backward	74.08%
Spores	96.82%	Seedless	84.61%	Composed	73.89%
Bryophytes	96.60%	Reproduction	83.58%	Consists	73.89%
Liverworts	95.78%	Tissues	83.06%	Cell	73.69%
Chloroplasts	95.78%	Feeding	83.06%	Processes	73.40%
Rhizome	95.75%	Parasitic	83.06%	Organism	73.34%
Fungi	95.73%	Structure	81.36%	Including	73.19%

Table 22 shows the learner-judged complexity of words across the reading texts, revealing a clear gradation of difficulty. Nearly all participants rated scientific terms like Giardia (99.64%), Chlamydomonas (99.48%), Phloem (99.36%), and Euglena (99.26%) as highly complex. Other technical words, Pseudopodia (99.06%), Leishmania (98.96%), Flagella (98.82%), and Mitochondria (98.73%), were similarly challenging. Words of moderate complexity (73–95%) included Moist (83.06%), Reaction (81.99%), and Coordination (78.84%), while Leaves (74.62%), Backward (74.08%), and Organism (73.34%) were recognized as complex by many students.

4.1.3. Dimensional complexity of linguistic feature in the reading texts

The analysis of the dimensional complexity of linguistic feature identified (phonological, lexical, and semantic, or in combination), in the reading texts, by students, revealed distinct patterns across the three dimensions (see Table 2). Students identified words as complex in a single dimension, across two dimensions, or simultaneously in all the three indicating that the texts are generally considered complex.

Table 23

Proportion of students identified words complex (%) & number of words) (n = 193)

Dimensional Complexity	Number of words in each text (n, %)			
	Text 1 (53 words)	Text 2 (98 words)	Text 3 (106 words)	Text 4 (55 words)
Phon	9 (17%)	16 (16%)	17 (16%)	3 (5%)
Lex	5 (9%)	9 (9%)	13 (12%)	7 (13%)
Sem	6 (11%)	11 (11%)	15 (14%)	9 (16%)
Phon & Lex	3 (6%)	6 (6%)	7 (7%)	2 (4%)
Phon & Sem	6 (11%)	9 (9%)	9 (8%)	4 (7%)
Lex & Sem	3 (6%)	6 (5%)	8 (8%)	6 (11%)
Phon, Lex, & Sem	7 (13%)	17 (17%)	15 (14%)	3 (5%)
Words Marked complex (n, %)	39 (74%)	74 (76%)	84 (79%)	34 (62%)
Words Marked Not complex (n, %)	14 (26%)	24 (24%)	22 (21%)	21 (38%)
Students Marked Words Complex (%)	6–74%	5–76%	7–79%	4–62%

Note. n (number of words marked complex), Phon (phonological complexity), Lex (lexical complexity), Sem (semantic complexity)

As table 23 shows, across the four texts, learners perceived varying types of linguistic complexity. Phonological complexity was most common in Texts 1–3 (16–17%) but lower in Text 4 (5%), while lexical and semantic complexities were moderate, with semantic features slightly higher in Text 4 (16%). Combinations of dimensions, including phonological, lexical, and semantic, also appeared, most frequent in Texts 2 (17%) and 3 (14%). Most words were judged complex, ranging from 62% in Text 4 to 79% in Text 3.

4.1.4. Lexical density of reading texts in the science textbook

Ure (1971) and Halliday (2009) define lexical density as a measure of the proportion of content words, showing that written, especially scientific, texts are more lexically dense than spoken language. They consider texts with 60–70% density as high and those above 70% as very high. Based on this framework, all four reading texts are lexically dense and characteristic of written scientific discourse (see Table 25).

Table 24

Lexical density of the reading texts based on Ure's (1971) measure and Halliday's (2209) scientific language framework

Reading Text	Total Words	Lexical Words	Lexical Density (%)
Text 1	69	48	.70
Text 2	183	141	.77
Text 3	165	129	.78
Text 4	120	83	.69

Table 24 shows that all four reading texts are highly dense, confirming their alignment with written scientific discourse. Text 3 (78%) and Text 2 (77%) exhibit very high lexical density, indicating a greater informational load, while Text 1 (70%) and Text 4 (69%) fall within the high-density range.

4.1.5. Lexical sophistication of reading texts in the science textbook

Lexical sophistication in this study was measured using the Tool for the Automatic Analysis of Lexical Sophistication (TAALES), which evaluates vocabulary difficulty based on word frequency and familiarity from corpora such as the Corpus of Contemporary American English (COCA). It defines sophistication as the proportion of low-frequency content words, with higher proportions indicating greater difficulty and cognitive demand. In this study, words identified as complex by 40%–70% of students represent moderate to high lexical sophistication, with higher percentages reflecting increased vocabulary difficulty (Kyle et al., 2018; Ibrahim et al., 2019). This method offers a reliable, corpus-based approach to assessing the lexical demands of the texts (see Table 25).

Table 25

Lexical sophistication indices of the four reading texts based on the proportion of low-frequency content words calculated using TAALES.

Text	Total Words	Content Words	Low-Frequency Words	Lexical Sophistication (%)
Text 1	69	48	21	.440
Text 2	183	141	67	.475
Text 3	165	129	66	.511
Text 4	120	83	24	.289

Table 25 presents the lexical sophistication of the reading texts, measured as the proportion of low-frequency words among content words. The results show that Text 3 has the highest lexical sophistication (0.511; 66/129), followed by Text 2 (0.475; 67/141) and Text 1 (0.440; 21/48), while Text 4 has the lowest level (0.289; 24/83), indicating greater reliance on familiar, high-frequency words.

4.1.6. Lexical semantic cohesion in the science reading texts

Lexical diversity, measured by the Type–Token Ratio (TTR), indicates how varied a text's vocabulary is by comparing unique words (types) to total words (tokens). Since TTR is affected by text length, adjusted measures such as Root TTR (RTTR) and Corrected TTR (CTTR) are used for more reliable analysis. Higher values reflect greater lexical variety and complexity, while lower values indicate more repetition. These measures provide a systematic way to assess the lexical richness of texts and their potential cognitive demands on readers (see Tables 26 and 27).

Table 26

Type–Token Ratio (TTR) of the four reading texts, showing raw lexical diversity based on the proportion of unique words to total words.

Text	Tokens (Total Words)	Types (Unique Words)	TTR
Text 1	69	46	.676
Text 2	183	117	.666
Text 3	165	107	.652
Text 4	120	73	.624

Text 1 recorded the highest TTR (0.676), indicating the greatest lexical diversity, though this may be influenced by its shorter length. Text 2 showed a similarly high TTR (0.666) despite having the largest number of tokens, suggesting strong and consistent vocabulary use. Text 3 demonstrated moderate lexical diversity (0.652), while Text 4 had the lowest TTR (0.624), reflecting comparatively higher word repetition.

Table 27

Adjusted measures of lexical diversity (Root TTR and Corrected TTR) for the four reading texts, controlling for text length to provide a reliable comparison of vocabulary variety.

Text	Tokens	Types	RTTR = Types ÷ √Tokens	CTTR = Types ÷ √ (2 × Tokens)
Text 1	69	46	5.58	3.90
Text 2	183	117	8.65	6.11
Text 3	165	107	8.36	5.91
Text 4	120	73	6.67	4.71

Table 27 presents lexical diversity using length-adjusted measures, RTTR and CTTR. RTTR values range from 5.58 in Text 1 to 8.65 in Text 2, with Text 3 also high (8.36), indicating greater lexical variety in Texts 2 and 3. CTTR shows a similar pattern in which Text 2 (6.11) and Text 3 (5.91) have the highest values, followed by Text 4 (4.71) and Text 1 (3.90). These results indicate that Texts 2 and 3 are more lexically diverse, while Texts 1 and 4 are relatively more repetitive, independent of text length.

Table 28.

Summary of textbook linguistic complexity across four reading texts

LINGUISTIC COMPLEXITY INDICATORS				
READING TEXT	LEARNER DIFFICULTY (>50%)	LEXICAL DENSITY (%)	SOPHISTICATION (COMPLEXITY INDEX)	DIVERSITY (CTTR)
TEXT 1	67%	70%	0.440	3.90
TEXT 2	72%	77%	0.475	6.11
TEXT 3	74%	78%	0.511	5.91
TEXT 4	53%	69%	0.289	4.71

Table 28 shows the multidimensional linguistic complexity analysis of reading texts in the 7th-grade general science textbook. It indicates that all of the reading texts are linguistically complex for learners, with Texts 1–3 consistently classified as "linguistically complex" and only Text 4 as "moderately complex", supported by high learner difficulty scores (53%–74%), elevated lexical density (69%–78%), and relatively high complexity index values (0.289–0.511), all of which reflect dense informational content and a heavy concentration of technical vocabulary typical of scientific discourse.

4.2. Relationships of Students Perceived Linguistic Competence, Textbook Linguistic Complexity, Engagement Profiles, and Science Achievement

Results presented in Table 29 show the correlations among the study variables, including dimensions of perceived linguistic competence, perceived textbook linguistic complexity, dimensions of engagement profiles, and science achievement.

Table 29

Bivariate Pearson's correlation results (n = 500)

Constructs	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Sci Ach	1								
(2) PPLC	.293**	1							
(3) PLLC	.346**	.392**	1						
(4) PSLC	.352**	.380**	.435**	1					
(5) PTLC	-.416**	-.379**	-.468**	-.472**	1				
(6) COG	.461**	.331**	.562**	.489**	-.412**	1			
(7) BEH	.513**	.343**	.459**	.426**	-.381**	.435**	1		
(8) EMOT	.441**	.360**	.351**	.419**	-.367**	.446**	.502**	1	
(9) AGNT	.453**	.322**	.433**	.422**	-.427**	.375**	.437**	.401**	1

Note. **. Correlation is significant at the 0.01 level (2-tailed); PPLC, perceived phonological linguistic competence; PLLC, perceived lexical linguistic competence; PSLC, perceived semantic linguistic competence; PTLC, perceived textbook linguistic complexity; COG, cognitive engagement; EMO, emotional engagement; BEH, behavioural engagement; AGNT, agentic engagement

Table 28 presents correlations among the study variables. Science achievement was significantly and positively correlated with phonological ($r = .293$, $p < .01$), lexical ($r = .346$, $p < .01$), and semantic competence ($r = .352$, $p < .01$), while it showed a significant negative correlation with perceived textbook linguistic complexity ($r = -.416$, $p < .01$). Similarly, all engagement dimensions were positively associated with science achievement ($r = .441$–$.513$, $p < .01$) but negatively associated with textbook linguistic complexity (cognitive: $r = -.412$; behavioural: $r = -.381$; emotional: $r = -.367$; agentic: $r = -.427$; all $p < .01$).

4.3. Direct and Indirect Effects

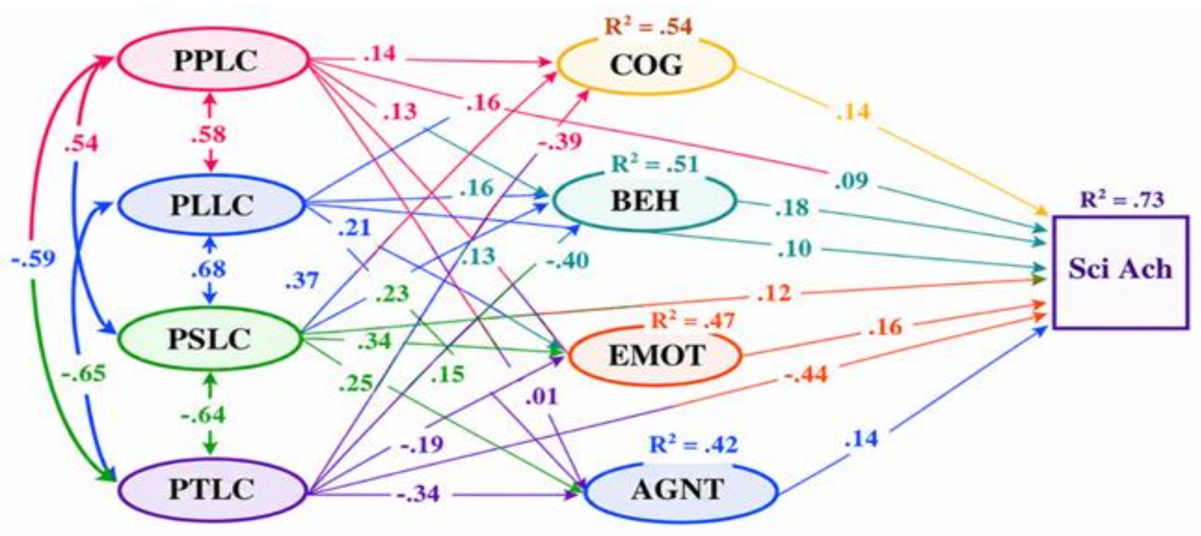
This section presents the direct and indirect effects of the hypothesized model. Examining direct effects first is important for accurately interpreting mediation relationships and avoiding biased estimates of indirect effects (Collier, 2020). Accordingly, both pathways were analyzed to understand how students' perceptions of linguistic factors influence science achievement through engagement dimensions.

4.3.1. Direct effects of perceived linguistic competence and perceived textbook linguistic complexity on students' engagement profiles and science achievement

Using SEM, the study examined the direct effects of students' perceived linguistic competence, perceived textbook linguistic complexity, and engagement profiles on science achievement. The hypothesized model was tested to determine how these perceptions influence science achievement through engagement dimensions. Figure 8 presents the structural relationships among the study variables, with standardized path coefficients and R^2 values indicating the explanatory strength of the model. The results show that the full structural model accounted for 73% of the variance in students' science achievement ($R^2 = .73$), demonstrating substantial predictive power.

Figure 8

The final mediation model of dimensions of engagement profiles in the link among perceived linguistic competence, textbook linguistic complexity, and science achievement



Note: All displayed coefficients are standardized path coefficients; PPLC (perceived phonological linguistic competence); PLLC (perceived lexical linguistic competence); PSLC (perceived semantic linguistic competence); COG (cognitive engagement); EMO (emotional engagement); BEH (behavioral engagement); ACH (science achievement).

The structural model also revealed statistically meaningful direct effects of the four latent predictors on science achievement. Specifically, PTLC demonstrated the strongest negative direct effect ($\beta = -.44$), indicating that higher PTLC was associated with lower science achievement. This was followed by PSLC, which showed a positive direct effect ($\beta = .12$), PLLC ($\beta = .10$), and PPLC exhibited the weakest direct effect on science achievement ($\beta = .09$).

More specifically, the three dimensions of students perceived linguistic competence (PPLC, PLLC, and PSLC), and perceived textbook linguistic complexity (PTLC), significantly predicted the different forms of student engagement. Together, these variables explained 54% of the variance in cognitive engagement ($R^2 = .54$), 51% of the variance in behavioral engagement ($R^2 = .51$), 47% of the variance in emotional engagement ($R^2 = .47$), and 42% of the variance in agentic engagement ($R^2 = .42$).

In turn, the four engagement dimensions were positively associated with science achievement, although the magnitude of the effects varied. Behavioral engagement emerged as the strongest direct predictor of science achievement ($\beta = .18$), followed by emotional engagement ($\beta = .16$) and cognitive and agentic engagement ($\beta = .14$).

The structural model showed that perceived linguistic competence positively predicted engagement profiles. Specifically, phonological competence (PPLC) had significant positive effects on cognitive ($\beta = .142$, C.R. = 2.949, 95% CI [.099, .271], $p = .013$), behavioural ($\beta = .131$, C.R. = 2.825, 95% CI [.089, .243], $p = .021$), and emotional engagement ($\beta = .129$, C.R. = 2.077, 95% CI [.069, .215], $p = .023$). Its effect on agentic engagement was not significant ($\beta = .013$, C.R. = .264, 95% CI [−.092, .126], $p = .788$), as the C.R. was below ±1.96 and the confidence interval included zero.

The analysis of direct effects examines how perceived linguistic competence and textbook linguistic complexity directly influence science achievement, independent of mediators. This approach identifies each predictor's unique contribution while controlling for other variables, and assessing the magnitude and significance of these effects reveals the strength and direction of the relationships among the constructs (see Table 30).

Table 30.

The direct effects of the predictor variables on the dependent variables

Dependent Variables	Predictors	B	S.E.	C.R.	95% CI	*β*	p-value
COG	PPLC	.115	.039	2.949	[.099, .271]	.142	.013
BEH	PPLC	.113	.040	2.825	[.089, .243]	.131	.021
EMOT	PPLC	.108	.052	2.077	[.069, .215]	.129	.023
AGNT	PPLC	.011	-.043	.264	[-.092, .126]	.013	.788
COG	PLLC	.135	.042	3.255	[.027, .308]	.164	.022
BEH	PLLC	.117	.043	2.725	[.024, .292]	.155	.022
EMOT	PLLC	.175	.046	3.776	[.079, .356]	.212	.003
AGNT	PLLC	.131	.050	2.639	[.004, .300]	.147	.044
COG	PSLC	.326	.045	7.216	[.237, .509]	.368	.000
BEH	PSLC	.184	.045	4.054	[.093, .365]	.227	.001
EMOT	PSLC	.322	.054	6.007	[.195, .473]	.336	.000
AGNT	PSLC	.224	.049	4.591	[.120, .395]	.254	.000
COG	PTLC	-.365	.054	-6.788	[-.531, -.263]	-.394	.000
BEH	PTLC	-.342	.050	-6.786	[-.551, -.261]	-.404	.000
EMOT	PTLC	-.172	.057	-3.018	[-.053, -.209]	-.191	.015
AGNT	PTLC	-.315	.048	-6.616	[-.487, -.210]	-.340	.000
Sci Ach	PPLC	.850	.349	2.434	[.040, .244]	.087	.017
Sci Ach	PLLC	.834	.309	2.699	[.109, .296]	.102	.005
Sci Ach	PSLC	1.013	.414	2.447	[.086, .236]	.121	.001
Sci Ach	PTLC	-4.810	.497	-9.674	[-.043, -.225]	-.440	.000
Sci Ach	COG	1.640	.421	3.897	[.077, .251]	.142	.002
Sci Ach	BEH	2.331	.471	4.951	[.082, .244]	.197	.000
Sci Ach	EMOT	1.751	.361	4.854	[.014, .163]	.160	.000
Sci Ach	AGNT	1.547	.424	3.649	[.563, .340]	.139	.007

Note. B represents the unstandardized regression coefficient, S.E. denotes the standard error, C.R. indicates the critical ratio, β is the standardized regression coefficient, and p corresponds to the significance level ($p < .001$, $p < .01$, $p < .05$). The variables are defined as follows: PPLC, perceived phonological linguistic competence; PLLC, perceived lexical linguistic competence; PSLC, perceived semantic linguistic competence; PTLC, perceived textbook linguistic complexity; COG, cognitive engagement; EMOT, emotional engagement; BEH, behavioural engagement; AGNT, agentic engagement; and Sci Ach, science achievement.

Perceived lexical linguistic competence (PLLC) significantly predicted all four engagement dimensions: cognitive (β = .164, C.R. = 3.255, 95% CI [.027, .308], p = .022), behavioural ($\beta = .155$, C.R. = 2.725, 95% CI [.024, .292], $p = .022$), emotional ($\beta = .212$, C.R. = 3.776, 95% CI [.079, .356], $p = .003$), and agentic engagement ($\beta = .147$, C.R. = 2.639, 95% CI [.004, .300], $p = .044$). In all cases, the C.R. values exceeded the critical threshold and the confidence intervals excluded zero, confirming statistical significance.

Perceived semantic linguistic competence (PSLC) exhibited the strongest positive correlations with engagement across all dimensions: cognitive ($\beta = .368$, C.R. = 7.216, 95% CI [.237, .509], $p < .001$), behavioural ($\beta = .227$, C.R. = 4.054, 95% CI [.093, .365], $p = .001$), emotional ($\beta = .336$, C.R. = 6.007, 95% CI [.195, .473], $p < .001$), and agentic engagement ($\beta = .254$, C.R. = 4.591, 95% CI [.120, .395], $p < .001$). The large C.R. values and non-zero confidence intervals indicate robust and consistent effects.

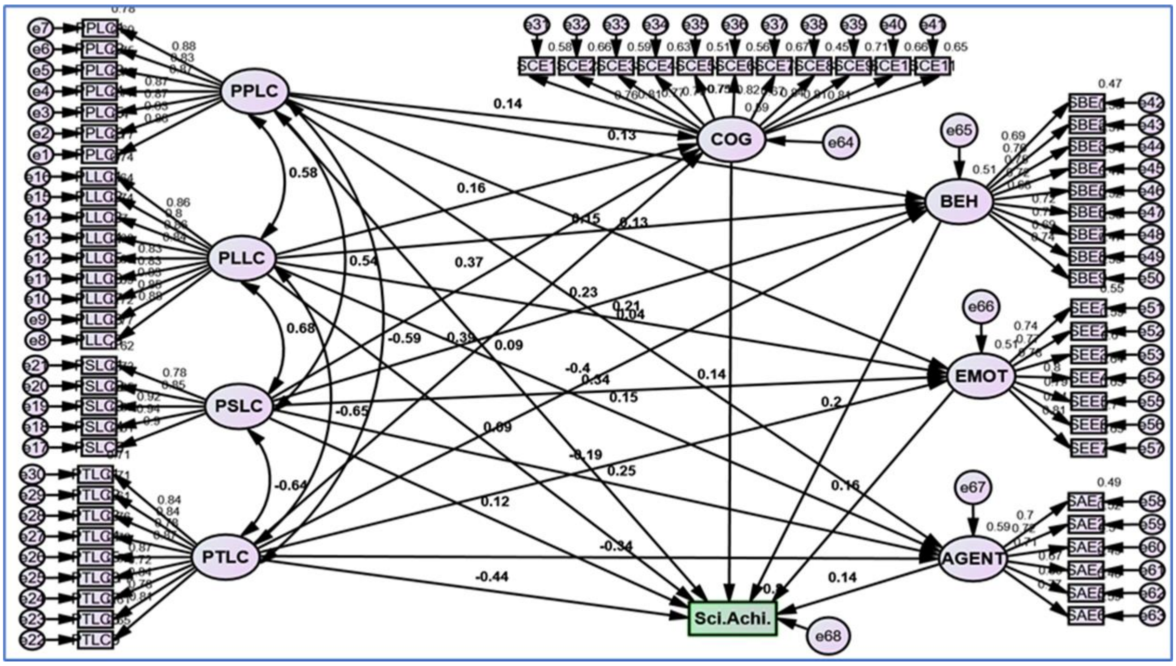
Conversely, perceived textbook linguistic complexity (PTLC) demonstrated significant negative effects on cognitive ($\beta = -.394$, C.R. = −6.788, 95% CI [−.531, −.263], $p < .001$), behavioural ($\beta = -.404$, C.R. = −6.786, 95% CI [−.551, −.261], $p < .001$), emotional ($\beta = -.191$, C.R. = −3.018, 95% CI [−.209, −.053], $p = .015$), and agentic engagement ($\beta = -.340$, C.R. = −6.616, 95% CI [−.487, −.210], $p < .001$). All confidence intervals excluded zero, confirming statistically significant negative correlations.

In predicting science achievement, semantic (PSLC, $\beta = .121$, C.R. = 2.447, $p = .001$), lexical (PLLC, $\beta = .102$, C.R. = 2.699, $p = .005$), and phonological competence (PPLC, $\beta = .087$, C.R. = 2.434, $p = .017$) had significant positive direct effects, while perceived textbook linguistic complexity (PTLC) had a strong negative effect ($\beta = -.440$, C.R. = −9.674, $p < .001$). All engagement dimensions also positively predicted science achievement, with behavioural engagement having the strongest impact ($\beta = .197$, $p < .001$), followed by emotional ($\beta = .160$, $p < .001$), cognitive ($\beta = .142$, $p = .002$), and agentic engagement ($\beta = .139$, $p = .007$).

The direct effects on achievement are relatively small, suggesting that multidimensional engagement partially mediates the impact of linguistic perceptions on science achievement (see Figure 9).

Figure 9

Full SEM of the effects of perceived linguistic competence and textbook linguistic complexity on science achievement via engagement profiles among 7th-grade students (standardized coefficients are reported)



Note. PPLC (perceived phonological linguistic competence); PLLC (perceived lexical linguistic competence); PSLC (perceived semantic linguistic competence); COG (cognitive engagement); EMO (emotional engagement); BEH (behavioural engagement); ACH (science achievement).

4.3.2. The mediating role of engagement profiles in the relationship between perceived linguistic competence, perceived textbook linguistic complexity, and science achievement

While students' perceptions of linguistic competence and textbook complexity had direct effects on science achievement, the study found that these relationships operate mainly indirectly through engagement dimensions. Semantic, lexical, and phonological competence, as well as textbook linguistic complexity, significantly influenced cognitive, behavioural, emotional, and agentic engagement, which in turn affected science achievement. This indicates that students' linguistic perceptions shape performance primarily by enhancing their multidimensional engagement.

The indirect and total effects of students perceived linguistic competence and textbook linguistic complexity on science achievement through engagement dimensions were examined. Using user-defined estimands in AMOS, both indirect effects and overall effects (direct plus indirect) were estimated, providing a comprehensive view of how these predictors influence science outcomes (see Table 31).

Table 30 shows that students' perceptions of linguistic factors had significant indirect effects on science achievement through engagement dimensions, with one exception. For phonological competence (PPLC), significant indirect effects were found via cognitive (Estimate = .189, 95% CI [.161, .265], $p = .001$), behavioural (Estimate = .263, 95% CI [.135, .385], $p < .001$), and emotional engagement (Estimate = .149, 95% CI [.119, .351], $p = .002$), while the pathway through agentic engagement was not significant (Estimate = .017, 95% CI [−.191, .285], $p = .649$). The combined indirect effect of PPLC across all four engagement dimensions was significant (Estimate = 1.003, 95% CI [.336, 1.758], $p = .002$).

Similarly, PLLC demonstrated significant indirect effects via cognitive engagement (Estimate = .221, 95% CI [.030, .618], $p = .018$), behavioural engagement (Estimate = .273, 95% CI [.041, .683], $p = .001$), emotional engagement (Estimate = .306, 95% CI [.163, .838], $p < .001$), and agentic engagement (Estimate = .203, 95% CI [.018, .577], $p = .035$). The total indirect effect of PLLC was significant (Estimate = .518, 95% CI [.498, .987], $p = .008$), suggesting that perceptions of textbook linguistic complexity were transmitted to science achievement through all engagement dimensions.

PSLC exhibited the strongest pattern of mediation effects. Significant indirect effects were found via cognitive engagement (Estimate = .535, 95% CI [.158, 1.057], $p = .005$), behavioral engagement (Estimate = .429, 95% CI [.137, .971], $p = .007$), emotional engagement (Estimate = .564, 95% CI [.259, .999], $p < .001$), and agentic engagement (Estimate = .347, 95% CI [.238, 1.029], $p = .009$). The total indirect effect of PSLC was substantial and statistically significant (Estimate = 1.875, 95% CI [1.028, 2.577], $p < .001$).

Table 31

Indirect and total effects on science achievement (User-defined estimands result using AMOS) (n = 500)

Variables		**Parameters**			
Indirect Effect of:	**Mediators**	**Estimate**	**Lower**	**Upper**	**P-value**
PPLC	COG	.189	.161	.265	.001
PPLC	BEH	.263	.135	.385	.000
PPLC	EMOT	.149	.119	.351	.002
PPLC	AGNT	.017	-.191	.285	.649
PLLC	COG	.221	.030	.618	.018
PLLC	BEH	.273	.041	.683	.001
PLLC	EMOT	.306	.163	.838	.000
PLLC	AGNT	.203	.018	.577	.035
PSLC	COG	.535	.158	1.057	.005
PSLC	BEH	.429	.137	.971	.007
PSLC	EMOT	.564	.259	.999	.000
PSLC	AGNT	.347	.238	1.029	.009
PTLC	COG	-.499	-1.474	-.221	.000
PTLC	BEH	-.597	-1.640	-.279	.000
PTLC	EMOT	-.326	-1.099	-.287	.014
PTLC	AGNT	-.487	-1.066	-.157	.004
Total Indirect Effect of:					
PLLC	Via COG, BEH, EMOT, AGNT	.518	.498	.987	.008
PPLC	Via COG, BEH, EMOT, AGNT	1.003	.336	1.758	.002
PSLC	Via COG, BEH, EMOT, AGNT	1.875	1.028	2.577	.000
PTLC	Via COG, BEH, EMOT, AGNT	-2.009	-2.938	-1.531	.000
Total Effect of:	**Paths**				
PLLC	(Indirect + Direct)	1.368	.632	1.733	.000
PPLC	(Indirect + Direct)	1.837	.836	2.824	.000
PSLC	(Indirect + Direct)	2.888	.763	3.649	.000
PTLC	(Indirect + Direct)	-4.819	-6.456	-3.652	.000

Note. PPLC, perceived phonological linguistic competence; PLLC, perceived lexical linguistic competence; PSLC, perceived semantic linguistic competence; PTLC, perceived textbook linguistic complexity; COG, cognitive engagement; EMOT, emotional engagement; BEH, behavioural engagement; and AGNT, agentic engagement.

In contrast, PTLC demonstrated significant negative indirect effects through cognitive engagement (Estimate = −.499, 95% CI [−1.474, −.221], $p < .001$), behavioral engagement

(Estimate = −.597, 95% CI [−1.640, −.279], $p < .001$), emotional engagement (Estimate = −.326, 95% CI [−1.099, −.287], $p = .014$), and agentic engagement (Estimate = −.487, 95% CI [−1.066, −.157], $p = .004$). The total indirect effect of PTLC was also significant and negative (Estimate = −2.009, 95% CI [−2.938, −1.531], $p < .001$).

Regarding total effects, which combined both direct and indirect pathways, PSLC demonstrated the strongest overall positive effect on science achievement (Estimate = 2.888, 95% CI [.763, 3.649], $p < .001$), followed by PPLC (Estimate = 1.837, 95% CI [.836, 2.824], $p < .001$) and PLLC (Estimate = 1.368, 95% CI [.632, 1.733], $p < .001$). In contrast, PTLC exerted a strong overall negative effect (Estimate = −4.819, 95% CI [−6.456, −3.652], $p < .001$).

CHAPTER FIVE

DISCUSSION AND IMPLICATIONS

5. Introduction

The present study aimed to investigate the effects of perceived linguistic competence and textbook linguistic complexity on science achievement via engagement profiles among seventh-grade students. Recognizing that academic success in science is shaped by both learners' self-perceptions and the linguistic demands of instructional materials, this research sought to clarify how these factors interact to influence achievement outcomes. The discussion that follows is organized in accordance with the stated research objectives and research questions, providing a structured interpretation of the findings in relation to the study's conceptual framework.

5.1. Textbook Linguistic Complexity

The linguistic complexity of reading texts in the 7th-grade science textbook was analysed using both student judgments and computational measures. Words that students found complex were triangulated with insights from systemic functional linguistics (Halliday, 2009) and metrics from TAALES and TAACOS, providing consistent theoretical and empirical evidence of text complexity. This approach improves on traditional readability formulas like Flesch–Kincaid, which rely mainly on sentence length and syllable counts and overlook deeper phonological, lexical, and semantic features (Best et al., 2005; Fang, 2005; Nadeem & Ostendorf, 2018).

5.1.1. Linguistic complexity of reading texts

The study provides convergent evidence that 7th-grade General Science reading texts are linguistically complex across multiple dimensions. Both student reading judgment task and computational indices indicate high lexical density, sophistication, and diversity at the word level. This alignment reinforces the credibility of the results, indicating that the observed difficulty arises from consistent characteristics of the text itself rather than from individual learner perceptions (Crossley et al., 2014; Crossley et al., 2023; Davis et al., 2017).

Student judgments reveal pervasive lexical difficulty. Of the 312 words analyzed, 142 words (68.27%), were identified as complex by at least 50 percent of participants, and 111 words (24.00%), were identified as complex by at least 70 percent of participants. The magnitude and consistency of these proportions indicate broader lexical complexity of reading texts in the science textbook. This pattern is consistent with lexical threshold theory, which posits that comprehension declines when unfamiliar vocabulary exceeds a critical proportion of the text, thereby constraining cognitive processing and limiting meaning construction (Laufer, 2013, 2016; Ng et al., 2020). When technical and low-frequency vocabulary dominates, comprehension deteriorates (Laufer & Nation, 1995; Nation, 2013, 2022).

Across nested thresholds of 40%, 50%, and 70% threshold, complex patterns remained stable. Between 53 percent and 75 percent of unique lexical words were judged complex at the 50% criterion across texts, and a substantial proportion remained complex even at the stricter 70% threshold. The robustness of these distributions supports the reliability of learner judgments and aligns with established methodologies in lexical complexity research demonstrating that aggregated learner ratings correspond to measurable linguistic features (Crossley et al., 2017, 2019; Laufer, 2016).

The words that posed the greatest difficulty were consistently domain-specific scientific words such as *Giardia, Chlamydomonas, phloem, Euglena, mitochondria, xylem, cilia, pteridophytes,* and *bryophytes*. These words tend to occur infrequently, exhibit phonetic complexity, and are often derived from Greek or Latin origins. Their central role in conveying scientific meaning further intensifies their difficulty, since understanding key processes, classifications, and structures depends directly on grasping these words. This finding aligns with existing research in which scientific discourse as lexically dense and heavily dependent on specialized vocabulary that compresses processes into abstract nominal forms and increase semantic opacity (Fang, 2006, 2016; Halliday, 2009; Hu et al., 2021).

Notably, difficulty extended beyond highly technical nomenclature to include moderately abstract academic vocabulary such as *reaction, application,* and *coordination*. These terminologies require inferential processing and conceptual integration rather than surface recognition. Their perceived complexity supports the view that academic vocabulary, even when not strictly technical, constitutes a substantial barrier in content-area reading (Nation, 2013). Words with dual every day and scientific meanings, such as *energy* and *reaction*, may further increase cognitive load by requiring contextual disambiguation (Best et al., 2005; Best et al., 2005, Wellington & Osborne, 2001).

Phonological complexity emerged as an additional source of difficulty. Multisyllabic forms such as *Giardia, Chlamydomonas, and Pseudopodia* were frequently identified as difficult to pronounce. Pronunciation difficulty can impede decoding fluency and slow lexical access, particularly when combined with unfamiliar morphology (Nation, 2019; Schmitt, 2014; Woore, 2018). Psycholinguistic models of reading emphasize that inefficient lexical retrieval constrains working memory resources available for higher-order integration (Perfetti & Stafura, 2014). When phonological unfamiliarity, lexical rarity, and semantic abstraction co-occur, intrinsic cognitive load intensifies (Melby-Lervåg et al., 2012; Sweller, 2011).

Distributional analysis confirms the multidimensional nature of difficulty. Between 13% and 29% of words in individual texts were judged complex simultaneously across phonological, lexical, and semantic dimensions. Such clustering is theoretically significant. Phonological complexity impedes decoding, lexical unfamiliarity increases retrieval demands, and semantic abstraction elevates inferential requirements, and their co-occurrence magnifies processing demands and may exceed learners' available cognitive resources (Higginbotham & Reid, 2019; Krajcik & Sutherland, 2010; Borodkin & Faust, 2014; Johnson & Lepore, 2004).

From a systemic functional linguistic perspective, scientific texts achieve precision through compressed vocabulary, grammatical metaphor, and dense noun structures (Fang, 2005; Halliday, 2009; Schleppegrell, 2004). While these features allow complex ideas to be expressed concisely, they reduce redundancy and contextual support. The finding showed that the reading texts combine high information load with a high proportion of low-frequency words. All the four reading texts exceed typical benchmarks for lexical density (Ure, 1971), reflecting the tightly compressed style common in science textbooks (Fang, 2006; Wellington & Osborne, 2001).

Lexical complexity was most evident in low-frequency, domain-specific terminologies such as *protozoa, photosynthesize,* and *excretion*, as well as in derived and compound forms like *leaf-like* and *coordination*. Even more familiar words, such as *moist* and *leaves*, were perceived as complex when used in technical contexts, highlighting the range of lexical demand in science texts (Laufer, 2013; Nation, 2013). Low-frequency vocabulary slows word recognition and increases processing difficulty, especially when several specialized terminologies appear together (Nation, 2019; Kyle & Crossley, 2017).

The findings show that the reading texts in the textbook are linguistically complex at phonological, lexical, and semantic levels. Developing scientific literacy therefore requires not only conceptual understanding but also the ability to handle dense, abstract, and morphologically complex language (Phillips & Norris, 2009; Fang, 2016). When low-frequency, specialized terminologies cluster within compressed structures, cognitive load increases and comprehension depends on strong vocabulary knowledge (McComas, 2013). The findings support the view that the language of science textbooks is a significant, multidimensional barrier for middle-grade learners in science education.

5.1.2. Automated computational analysis of linguistic complexity in reading texts

A central contribution of this study lies in the systematic triangulation of learner-based judgments with computational indices of linguistic complexity, including lexical density, lexical sophistication, and adjusted lexical diversity. This integrated design reflects current methodological recommendations in applied linguistics, which emphasize combining perceptual and corpus-based measures to capture multidimensional textual difficulty (Bulté & Housen, 2019; Crossley et al., 2016). By aligning subjective evaluations with objective metrics, the analysis strengthens the validity of the findings.

Lexical density provides the first layer of explanation. In systemic functional terms, it distinguishes written from spoken language and reflects how information is packaged (Ure, 1971; Halliday, 2009). Scientific texts are typically dense because they rely on content words and compressed noun structures (Crossley et al., 2014; Davis et al., 2017). In this analysis, reading texts show very high and high density. Values above 0.70 are widely associated with heavy informational load in academic writing (Halliday, 2009, Ure, 1971). Such density concentrates meaning within fewer words, requiring readers to process more information with less support. The fact that the densest texts were also judged most difficult suggests that structural compression increases cognitive demand (Fang, 2005).

Lexical sophistication further intensifies the complexity of reading texts in which all the reading texts had the highest proportion of low-frequency words. Research consistently identifies low-frequency vocabulary as a key source of linguistic complexity because such words are less familiar to readers (Laufer & Nation, 1995). Corpus-based measures like TAALES provide reliable indicators of vocabulary complexity and processing demands (Crossley & McNamara, 2014). Low-frequency words require more effort to recognize and understand, which slows comprehension (Kyle et al., 2018; Laufer & Nation, 1995). Notably, the sophistication scores closely match students’ judgments in which the most low-frequency vocabulary also had the highest number of words perceived as complex. This alignment suggests that learners' perceptions reflect measurable lexical features.

Lexical diversity adds another layer to the textbook linguistic complexity. Adjusted type-token ratio measures show greater diversity in the treading texts, reflecting less repetition of key terms. Although variation can expand expressive range, limited repetition reduces lexical cohesion and opportunities for semantic reinforcement, which are important for comprehension (McNamara et al., 2014; Nation, 2019). In instructional settings, repeated exposure to words strengthens conceptual links and lowers inferential demands. Therefore, the combination of high density, high sophistication, and elevated diversity in the reading texts likely increases processing demands rather than supporting science learning.

The finding from cohesion analysis using TAACOS reinforces this view. Sparse lexical overlap combined with dense information reduces semantic transparency, forcing readers to expend extra effort decoding low-frequency terms. Cognitive theories of text processing highlight that repeated lexical links help build coherent mental representations, so limited repetition can hinder conceptual integration (Siregar, 2023).

The texts display highly compressed information, a high concentration of low-frequency vocabulary, and substantial adjusted lexical diversity. The alignment between computational measures and student judgments reflects the linguistic complexity of reading texts in middle school science materials. Frequent student-identified difficult words, high lexical density, elevated sophistication, and significant diversity create cumulative cognitive load, reflecting Halliday's (2009) characterization of scientific discourse as abstract and information-rich, and supporting frequency-based models of lexical difficulty (Crossley & McNamara, 2014) as well as research on academic vocabulary (McKeown et al., 2000).

The strong consensus among students indicates that complexity of terminologies reflects systematic linguistic properties rather than random variation. This alignment between subjective judgments and objective corpus-based measures reinforces the validity of the findings and provides a solid empirical basis for examining how textbook complexity may influence learner engagement and science achievement. The reading texts exhibited high phonological, lexical, and semantic complexity, consistent with models of scientific discourse and empirically validated through corpus-based analyses.

5.2. Findings of Structural Equation Modelling Analysis

This study also investigated the structural relationships among students perceived linguistic competence, perceived textbook linguistic complexity, and their science achievement, considering the mediating role of engagement profiles among 7th-grade students. Using a structural equation modeling, the analysis explored how students' self-perceptions of linguistic competence and their interpretations of textbook linguistic complexity influence engagement patterns, which in turn could affect academic performance in science. Based on the research objectives and research questions, this section discusses the findings that provide insights into the interplay of linguistic factors and engagement behaviors, emphasizing potential pathways for supporting student learning in linguistically demanding disciplines.

Bivariate correlations show that seventh-grade students' science achievement is positively associated with perceived linguistic competence and all dimensions of engagement, but negatively associated with perceived textbook complexity. Language skills, especially vocabulary, support understanding and achievement (Ardasheva et al., 2021; Snow, 2010; Zhu et al., 2023; Fang, 2006; Nation, 2022), consistent with Self-Efficacy Theory (Bandura, 1973, 1997), while complex textbooks reduce comprehension and motivation, particularly in multilingual contexts (Fang, 2016; Seid, 2016; Guthrie et al., 2012). Engagement, especially behavioral effort, strongly enhances achievement and may mediate these effects (Fredricks et al., 2004; Uçar & Sungur, 2017), with higher competence increasing engagement and textbook complexity reducing it (Ryan & Deci, 2000; Hu et al., 2022; Amendum et al., 2018; Rhodes et al., 2020).

5.2.1. Effects of perceived linguistic competence and perceived textbook linguistic complexity on science achievement

The present findings provide strong evidence that students' perceptions of their own linguistic competence and of textbook linguistic complexity exert significant, but opposing, effects on science achievement. The structural model accounted for 73% of the variance, highlighting that achievement depends not only on content knowledge or general cognitive ability but also on how learners assess their language skills relative to instructional demands. This supports disciplinary literacy perspectives, which view science learning as inherently tied to engagement with specialized language and texts (Goldman & Snow, 2015; Uccelli et al., 2015).

Consistent with communicative competence theory (Hymes, 1972; Canale & Swain, 1980), perceived linguistic competence positively predicted academic achievement. Students who feel confident in decoding terminology, interpreting symbols, and constructing meaning from scientific texts tend to perform better (Kieffer & Lesaux, 2012). This effect remains significant even when controlling for engagement, indicating that linguistic self-perceptions directly influence achievement (Mortimer & Scott, 2003). These results align with research showing that limited scientific vocabulary restricts conceptual understanding (Wellington & Osborne, 2001) and that language proficiency predicts both science performance and long-term learning growth (Guglielmi, 2012).

Semantic competence emerged as the most influential dimension of linguistic competence. This supports research showing that science learning depends on constructing and integrated meanings that links concepts, models, and explanations (Hahn et al., 2019; Yun, 2020). Studies also indicate that analogical reasoning and model-based explanations rely on semantic integration (Adúriz-Bravo, 2020; Haglund, 2012). Extending this work, the current findings show that students' perceptions of their semantic competence significantly predict science achievement, suggesting that confidence in organizing and connecting scientific meanings supports deeper conceptual understanding.

The findings are also resonated with broader disciplinary literacy research, which views language as integral to scientific practice rather than simply a tool. Science is constructed and communicated through dense vocabulary, nominalizations, symbols, and multimodal representations, making academic language proficiency essential for meaningful participation (Goldman & Snow, 2015; Uccelli et al., 2015). By showing a direct link from perceived linguistic competence to science achievement, this study provides empirical support for the idea that language is a central mechanism driving science learning.

In contrast, perceived textbook linguistic complexity showed a strong negative relationship with science achievement, emphasizing the need to align instructional demands with students' language resources. Texts with high lexical density and syntactic complexity impose heavy processing demands, and when students view them as overly difficult, cognitive effort is diverted toward decoding and parsing, reducing capacity for higher-order conceptual integration (Hackemann et al., 2022).

However, existing literature indicates that linguistic complexity is not inherently detrimental. Moderate complexity can enhance relational reasoning and cognitive engagement (Strohmaier et al., 2023). The negative effects seen here likely reflect perceptions of excessive, rather than optimal, complexity. When textual density exceeds students' linguistic capacity, working memory is overtaxed, limiting comprehension and knowledge construction (Tuominen, 2024). Additionally, linguistic self-concept interacts with task demands to influence comprehension outcomes (Neri et al., 2025).

The findings indicate that science achievement depends on the balance between perceived linguistic competence and perceived textual demand. When students view their language skills as sufficient for the complexity of instructional materials, achievement is supported; when perceived demands exceed competence, performance declines. This competence–demand alignment perspective integrates communicative competence theory, disciplinary literacy frameworks, and cognitive processing models, providing a comprehensive account of how language perceptions shape science learning outcomes.

5.2.2. Dimensions of engagement profiles as predictors of science achievement

The findings show that cognitive, behavioral, emotional, and agentic engagement each have significant, positive effects on seventh-grade science achievement. All four dimensions independently predicted performance, indicating that success in science depends not just on intellectual ability or linguistic competence but on students' active psychological and behavioral investment. This view aligns with the idea that engagement is a dynamic combination of cognitive effort, behavioral persistence, emotional involvement, and agentic participation (Fredricks et al., 2004; Reeve & Tseng, 2011; Skinner & Pitzer, 2012), and supports mediation models suggesting that engagement translates personal and contextual resources into measurable academic outcomes (Wang & Eccles, 2013; Xu et al., 2023).

Cognitive engagement emerged as a particularly strong predictor, highlighting the role of deep processing, metacognitive regulation, and conceptual integration in science learning. Mastery of scientific content requires interpreting symbols, integrating text and graphics, constructing evidence-based explanations, and evaluating competing claims, all of which demand sustained effort and strategic thinking (Fang, 2006, 2012; Snow & Uccelli, 2009; Wellington & Osborne, 2001). Cognitive engagement is the extent of psychological investment devoted to understanding complex material (Fredricks et al., 2004).

These results align with Strohmaier et al. (2023), who found that moderate to high linguistic complexity in STEM texts can enhance relational reasoning when students invest sufficient cognitive effort. Similarly, Rhodes et al. (2020) showed that cognitively demanding inquiry-based reading and writing tasks boost both behavioral and cognitive engagement, supporting deeper conceptual understanding. By linking cognitive engagement directly to achievement in a transitional middle school context, the present study extends this literature and underscores cognitive engagement as a crucial mechanism for navigating linguistically and conceptually dense science texts (National Research Council, 2012).

Behavioral engagement also had a strong positive effect on science achievement, reflecting actions such as sustained attention, effort, persistence, and active participation (Fredricks et al., 2004). In science, these behaviors are crucial, as conceptual mastery often relies on repeated experimentation, collaborative inquiry, and iterative problem-solving. Consistent with Bråten et al. (2022), the findings show that sustained effort and task-focused participation support achievement, particularly in contexts requiring prolonged engagement with challenging content (Uçar & Sungur, 2017).

Emotional engagement also significantly predicted science achievement, emphasizing the role of affect in sustaining motivation and persistence. This dimension includes interest, enjoyment, a sense of belonging, and low anxiety toward academic tasks (Fredricks et al., 2004). Positive emotional experiences can cause frustration in science, which is often perceived as abstract and demanding during early adolescence, supporting attention and intrinsic motivation (Wang & Degol, 2014). The findings confirm that students who enjoy and are interested in science perform better, aligning with evidence that emotional involvement sustains long-term engagement with disciplinary content (Ainley & Ainley, 2011).

Agentic engagement also had a significant direct effect on science achievement, highlighting the importance of students' proactive role in learning. Defined as students' constructive contributions to instruction, such as asking questions, seeking clarification, expressing preferences, and influencing classroom activities (Reeve, 2013), agentic behaviors help secure adaptive instructional responses (Reeve & Lee, 2014). Consistent with Reeve and Tseng (2011), the findings show that student-initiated discourse in inquiry-based science supports reasoning and knowledge construction. This underscores that learners who actively shape their learning environment are better able to achieve conceptual mastery.

While each engagement dimension independently predicted achievement, their combined effects suggest complementary and potentially synergistic influences. Meta-analyses indicate that cognitive and behavioral engagement most directly drive science performance, while emotional and agentic engagement provide motivational and contextual support that sustains effort and responsiveness (Lei et al., 2018; Li et al., 2024). The present findings reflect this pattern: cognitive and behavioral engagement drive performance through strategic processing and effort, whereas emotional engagement maintains motivation and agentic engagement aligns learning with instructional opportunities.

Importantly, these findings integrate with disciplinary literacy perspectives which view science learning as inherently shaped by specialized language and engagement with complex texts (Snow, 2010; Yore & Treagust, 2006). High levels of cognitive, behavioral, emotional, and agentic engagement enable students to convert linguistic and conceptual challenges into meaningful understanding, while disengagement can amplify the negative impact of complex texts (Neri et al., 2025; Tuominen, 2024). The results provide strong empirical support for models positioning multidimensional engagement as a central predictor of science achievement, showing that performance emerges from the coordinated interaction of deep cognitive processing, sustained behavioral effort, positive emotional investment, and proactive agentic participation. By demonstrating the direct and complementary contributions of these dimensions, the study reinforces engagement as the primary mechanism linking personal beliefs and contextual demands to academic success.

5.2.3. Effects of perceived linguistic competence on engagement profiles

The findings show that perceived linguistic competence, including phonological, lexical, and semantic aspects, has a strong positive effect on all four dimensions of student engagement. This suggests that students' confidence in their ability to understand and use academic language in science supports deeper thinking, active participation, positive emotional experiences, and proactive involvement in learning. This is consistent with prior research showing that linguistic competence fosters active knowledge construction rather than passive learning in science classrooms (Wellington & Osborne, 2001; Zhu et al., 2023).

The strongest effects were observed for cognitive engagement, particularly from perceived semantic and lexical competence. Consistent with Fang (2016), perceived semantic competence is especially influential, as it underpins relational thinking and evidence-based reasoning, encouraging greater cognitive investment in complex tasks. Cognitive engagement involves deep processing, metacognitive monitoring, and conceptual integration, all of which are essential in science learning, where students must coordinate technical vocabulary and explanatory models (Goldman & Snow, 2015). Scientific understanding depends heavily on engagement with linguistically complex and conceptually integrated texts (NRC, 2012). Confidence in interpreting specialized vocabulary and abstract meanings likely reduces cognitive load and supports deeper reasoning (Snow & Uccelli, 2009)

Behavioral engagement was also significantly predicted by all three competence dimensions, with particularly strong effects from lexical and semantic competence. The positive effect suggests that linguistic self-efficacy reduces participation barriers by helping students understand instructions, interpret tasks, and express ideas more confidently. Consistent with Schunk and DiBenedetto (2021), confidence in one's abilities supports persistence and self-regulation, which are central to behavioral engagement. Neri et al. (2025) further show that linguistic self-concept interacts with task demands to influence participation. The present findings extend this evidence by demonstrating that perceived lexical and semantic competence directly promote observable engagement in science classrooms.

Emotional engagement, including interest and enjoyment was also positively influenced by perceived linguistic competence, particularly lexical and semantic competence. Students who view themselves as linguistically capable are less likely to experience frustration or anxiety when engaging with complex scientific discourse and are more likely to maintain positive emotions and intrinsic motivation. This aligns with the views that that interest increases when learners feel competent that is central to sustained motivation and emotional engagement (Ainley & Ainley, 2011; Wang & Eccles, 2013). The relatively stronger effect of lexical competence is consistent with evidence that vocabulary knowledge reduces frustration and enhances enjoyment in working with technical texts (Uccelli et al., 2015).

Agentic engagement, defined as students' proactive contributions for their learning, was also significantly predicted by lexical and semantic competence, but not by phonological competence. This pattern is theoretically consistent, as agentic engagement depends on the ability to articulate ideas, negotiate meaning, and express interpretations, which rely more on vocabulary knowledge and semantic integration than on pronunciation alone (Reeve, 2013; Reeve & Tseng, 2011). The limited role of phonological competence suggests that accurate pronunciation, while helpful, does not by itself enable students to influence instructional discourse (Novianti & Syihabuddin, 2021). In contrast, lexical and semantic confidence support precise questioning and the expression of conceptual difficulties, thereby enhancing instructional interaction and understanding. This aligns with sociocultural perspectives (Vygotsky, 1978), which view language as a key tool for participation in cognitively demanding discourse.

The findings show a clear and theoretically consistent pattern in which perceived linguistic competence acts as a key driver of student engagement. Semantic competence has the strongest and most consistent influence, especially on cognitive and emotional engagement, while lexical competence strongly supports behavioral and agentic participation. Phonological competence contributes to cognitive, behavioral, and emotional engagement but does not independently promote proactive involvement.

5.2.4. Effects of perceived textbook linguistic complexity on engagement profiles

The study found that perceived textbook linguistic complexity (PTLC) is a significant contextual constraint that directly reduces multidimensional engagement in science learning. When seventh-grade students view their science textbooks as linguistically dense, syntactically complex, or conceptually overloaded, their cognitive effort, sustained participation, positive emotions, and proactive contributions are noticeably lowered. This finding indicates that instructional language is not neutral but acts as a critical factor that can limit students' motivation and engagement in science.

Accessible and appropriately challenging materials support sustained effort, active participation, and positive emotions, whereas overly demanding materials hinder these responses (Fang, 2016; Guthrie et al., 2012; Snow & Uccelli, 2009; Strohmaier et al., 2023). The findings indicate perceived textbook linguistic complexity as a critical barrier that reduces cognitive, behavioral, emotional, and agentic engagement. Strong negative impact was found on cognitive engagement aligns with the view that texts with high lexical density and complexity impose heavy extraneous processing demands (Hackemann et al., 2022; Arya et al., 2011). When students perceive this complexity as exceeding their linguistic resources, working memory is consumed by surface-level decoding, limiting capacity for deep conceptual integration, relational thinking, and evidence-based reasoning (Fang, 2016; Snow & Uccelli, 2009), and leading to declines in strategic processing and metacognitive regulation.

Behavioral and emotional engagement are both negatively affected by perceived textbook linguistic complexity. Behavioral engagement is reduced when students find texts linguistically difficult, often leading to frustration, discouragement, and avoidance of readings, discussions, and problem-solving tasks (Schuth et al., 2017; Sun, 2020). Emotional engagement is also weakened in which linguistically overwhelming texts can provoke confusion and frustration, particularly in abstract and technical subjects like science (Tuominen, 2024; Wang & Degol, 2014), reducing intrinsic motivation and students' emotional connection to the material (Amendum et al., 2018).

Agentic engagement was also negatively influenced by textbook perceived complexity. Confidence in articulating inquiries and negotiating meaning is essential for agentic participation (Reeve & Tseng, 2011). When textbooks are viewed as linguistically overwhelming, students may refrain from speaking up, fearing inadequate command of the requisite language, which suppresses initiative and limits opportunities for personalized scaffolding (Neri et al., 2025).

It should be noted that linguistic complexity does not invariably impair engagement. Moderate levels of complexity, when aligned with learners' zone of proximal development and accompanied by appropriate scaffolding, can stimulate deeper cognitive processing and sustained involvement (Strohmaier et al., 2023; August et al., 2009). However, the significant negative coefficients in the present study suggest that the perceived complexity of the textbooks might exceed students' manageable thresholds, transforming potential intellectual challenge into a source of disengagement.

5.2.5. Mediating roles of engagement profiles in the relationship among perceived linguistic competence, perceived textbook linguistic complexity, and science achievement

The findings also show that all four engagement dimensions partially mediated the effects of perceived linguistic competence (PPLC, PLLC, PSLC) and perceived textbook linguistic complexity (PTLC) on science achievement (Sci Ach). Significant indirect effects through these engagement profiles, along with substantial total effects, highlight multidimensional engagement as a key mechanism through which students' perceptions of language shape their academic performance.

5.2.6. Mediation of dimensions of engagement profiles in the relationship between dimensions of perceived linguistic competence and science achievement

The findings of the present study show that cognitive, behavioral, emotional, and agentic engagement significantly mediate the relationship between perceived linguistic competence and science achievement. While phonological, lexical, and semantic competence have direct positive effects on science achievement, much of their influence occurs indirectly through students' engagement profiles. This mediation indicates that linguistic self-perceptions boost science achievement not only by enhancing comprehension but also by promoting deeper intellectual, behavioral, emotional, and participatory involvement in learning (Skinner & Pitzer, 2012; Zhu et al., 2023; Wellington & Osborne, 2001).

Perceived phonological (PPLC), lexical (PLLC), and semantic (PSLC) linguistic competence exerted significant positive indirect effects on science achievement through the engagement dimensions, complemented by smaller direct effects that yielded strong total effects. The mediation was most pronounced for PSLC, driven by its strong correlations with cognitive and emotional engagement, which strongly predicted achievement, consistent with the view that semantic integration as essential for relational thinking, evidence-based reasoning, and conceptual mastery in science (Snow & Uccelli, 2009; Fang, 2016; Goldman & Snow, 2015). PLLC emerged as a broadly effective facilitator, aligning with evidence that lexical proficiency reduces comprehension barriers and supports motivational engagement across multiple dimensions (Ardasheva et al., 2021; Nation, 2022; Zhu et al., 2023).

Engagement is the immediate mechanism linking self-perceived competence to academic outcomes (Ferla et al., 2010; Roebers et al., 2012). Personal competencies influence achievement primarily through their effects on how students invest effort, regulate cognition, and participate in instructional processes (Schunk & DiBenedetto, 2021). Perceived linguistic competence represents a domain-specific psychological resource that enhances students' readiness to engage (Badrasawi et al., 2021; Kulgemeyer & Schecker, 2013; Lee & Orgill, 2021; MacKay, 2012). The significant indirect effects observed in this study confirm that engagement dimensions function as explanatory pathways through which linguistic competence translates into science achievement.

Cognitive engagement plays a central mediating role in science learning, which involves interpreting complex explanations, integrating symbolic representations, and constructing coherent conceptual frameworks. Students' competence in phonological decoding, lexical comprehension, and semantic integration facilitates metacognitive regulation and conceptual reasoning. For example, Goldman and Snow (2015) show that disciplinary literacy skills enhance deep engagement with scientific texts. The current findings indicate that linguistic competence promotes cognitive engagement, which in turn improves science achievement.

Behavioral engagement also mediates the link between perceived linguistic competence and science achievement. Bandura (1977, 1997) proposed that individuals' beliefs in their capabilities directly influence effort and persistence on challenging tasks. Students confident in their linguistic skills are more likely to engage in discussions, complete complex assignments, and persist in laboratory investigations. Empirical research supports this mechanism, indicating that stronger competence beliefs contribute to sustained engagement over time (Bråten et al., 2022; Schunk & DiBenedetto, 2021). The current mediation results confirm that behavioral engagement is a key pathway through which linguistic competence enhances science performance.

Emotional engagement further mediates the relationship between perceived linguistic competence and science achievement. Positive linguistic self-perceptions reduce apprehension and enhance learners' confidence when engaging with scientific texts and participating in classroom discourse. Students who feel capable in understanding scientific language are more likely to experience positive emotions, which enhance intrinsic motivation and resilience (Blankson et al., 2017). Feng and Hong (2022) indicate that adaptive emotional states support persistence and academic success. The observed indirect effects indicate that positive linguistic self-beliefs promote emotional engagement, which in turn facilitates higher science achievement.

Agentic engagement also mediates the relationship between perceived linguistic competence and science achievement. In science classrooms, students articulate hypotheses, justify reasoning, and negotiate meaning collaboratively. Those who perceive themselves as linguistically capable are more likely to exercise agency in shaping their learning. Neri and Retelsdorf (2022) show that linguistic self-concept predicts participation in linguistically demanding academic tasks. Students who perceive themselves as linguistically competent are more likely to actively contribute, ask questions, and shape their learning, which enhances science achievement (Haug & Ødegaard, 2014). Mediation analysis confirms that agentic engagement partly explains how linguistic competence promotes science achievement.

The findings indicate that multiple engagement dimensions collectively enhance the effect of perceived linguistic competence on science achievement. While direct effects remain, substantial indirect effects show that engagement is a central mechanism in which linguistic competence promotes cognitive investment, behavioral persistence, emotional involvement, and agentic participation, each contributing independently to achievement. This layered influence reflects a hierarchical process in which linguistic self-perceptions activate interconnected engagement pathways.

5.2.7. Mediation of dimensions of engagement profiles in the relationship between perceived textbook linguistic complexity and science achievement

The present study found that perceived textbook linguistic complexity (PTLC) strongly reduced science achievement through both direct effects and negative indirect effects via cognitive, behavioral, emotional, and agentic engagement. The mediation was strongest for cognitive, behavioral, and agentic engagement, with a smaller effect on emotional engagement. When textbooks are perceived as overly dense or semantically ambiguous, students' strategic processing, effort, participation, and positive affect decline, ultimately undermining performance (Nadeem & Ostendorf, 2018).

The strong negative mediation via cognitive and behavioral engagement aligns with evidence that excessive textual demands reduce strategic effort, persistence, and active participation in science tasks (Strohmaier et al., 2023; Fang, 2006; Snow & Uccelli, 2009). Suppressed agentic engagement reflects diminished confidence to ask questions, seek clarification, or negotiate meaning when instructional materials are linguistically overwhelming (Reeve & Tseng, 2011; Neri et al., 2025). The weaker mediation through emotional engagement corresponds to findings that frustration, anxiety, and reduced interest emerge when complexity exceeds perceived competence, though these effects may be partially mitigated by other motivational factors (Tuominen, 2024; Wang & Degol, 2014).

In multilingual transitional contexts such as Ethiopia, these findings are particularly salient. English-medium textbooks often impose linguistic demands that exceed students' current capacities, heightening disengagement and contributing to declines in science proficiency (Seid, 2016; Artzi et al., 2022). This pattern mirrors evidence linking high textual complexity in STEM materials to frustration, reduced motivation, and impaired comprehension, especially in multilingual transitional settings (Strohmaier et al., 2023; Berendes et al., 2018; Maufiroh et al., 2024; Seid, 2016).

The direct effects on science achievement indicate that engagement dimensions function as partial mediators. Perceived linguistic competence positively contributes to achievement, whereas PTLC exerts a strong negative influence, with engagement dimensions accounting for additional variance. These findings support multidimensional engagement frameworks, which propose that active involvement across cognitive, behavioral, emotional, and agentic domains translate linguistic perceptions into performance outcomes (Fredricks et al., 2004; Reeve & Tseng, 2011).

Cognitive, behavioral, emotional, and agentic engagement each positively predict science achievement, demonstrate that success depends on both cognitive skills and active psychological and behavioral involvement. Perceived linguistic competence, especially semantic competence, enhances achievement directly and indirectly via engagement, while perceived textbook linguistic complexity exerts negative effects. Engagement mediates these influences, confirming that linguistic competence serves as a cognitive and motivational resource, whereas excessive textual complexity constrains engagement and performance.

5.3. Implications of the Study

The findings of this study have important theoretical and practical implications by integrating two complementary aspects of evidence. The first is linguistic complexity of 7th-grade science textbook and the structural relationships among perceived linguistic competence, perceived textbook complexity, engagement, and science achievement.

5.3.1. Theoretical implications of the findings

The findings contribute theoretically by supporting systemic functional perspectives on scientific language. High lexical density, advanced lexical sophistication, and complex phonological, lexical, and semantic features demonstrate that middle school science texts exhibit characteristics of established scientific registers. Density values near or above 0.70 reflect informational compression and structural abstraction typical of scientific discourse. These results confirm that science knowledge is constructed through specialized linguistic forms, such as nominalization, technical terms, and condensed noun phrases, indicating that mastery of scientific content is inseparable from mastery of its linguistic structure.

The study further advances multidimensional models of text complexity by linking computational linguistic measures with students' perceptions of difficulty. Traditional readability formulas, limited to sentence length and syllables, overlook the layered nature of disciplinary texts. The findings show that complexity operates across phonological, lexical, semantic, and cohesion levels, and that students' perceived difficulty aligns closely with objective measures like lexical sophistication. This convergence integrates cognitive-linguistic perspectives on vocabulary processing with disciplinary literacy theory, highlighting that text complexity is both structurally embedded and psychologically experienced.

The findings inform cognitive load and lexical threshold theories. A high proportion of low-frequency vocabulary and dense lexical structures supports the idea that comprehension declines when vocabulary coverage falls below a critical threshold. From a cognitive load perspective, elevated lexical density and unfamiliar terminology increase intrinsic processing demands, reducing working memory resources for conceptual integration. Science learning requires simultaneous decoding and meaning construction, so heightened linguistic demands amplify cognitive strain, potentially limiting understanding and engagement. Linguistic complexity thus emerges as a critical determinant of processing efficiency in science learning.

Beyond text features, the structural model positions linguistic competence as foundational academic capital. Perceived phonological, lexical, and semantic competence predicted science achievement directly and indirectly, highlighting language proficiency as both a cognitive and motivational resource. Students confident in their linguistic abilities are more likely to invest effort, sustain engagement, and achieve academically. Thus, linguistic self-perception functions as cognitive–motivational capital, shaping participation and performance in disciplinary learning.

The mediation findings extend dimensions of engagement profiles, such as cognitive, behavioral, emotional, and agentic engagement operated as mechanisms linking linguistic perceptions to achievement, demonstrating that engagement is influenced not only by instructional context but also by students' capacity to navigate linguistic demands. Linguistic competence strengthened engagement across all dimensions, whereas perceived textbook complexity diminished engagement. Language, therefore, functions as a precursor to motivational investment and sustained participation in science learning.

Finally, integrating disciplinary literacy and motivational frameworks offers a notable theoretical contribution. Disciplinary literacy highlights science's specialized communicative practices, while engagement theory explains the psychological processes driving performance. By modeling how linguistic perceptions shape engagement and achievement, the study presents a unified framework in which text features influence psychological processes that determine academic outcomes. Language thus serves as the structural interface linking cognition and motivation, enhancing the conceptual coherence of science education research.

5.3.2. Practical implications of the findings

The findings have important implications for curriculum design and textbook development. High lexical density and sophistication suggest that instructional materials should balance disciplinary rigor with linguistic accessibility. Without reducing conceptual content, textbooks can reduce linguistic complexity through embedded definitions, glossaries, visual supports, and morphological explanations. Simplifying nominalizations, syntactic structures, and evenly distributing informational load can lower cognitive burden while maintaining scientific precision. Integrating multidimensional linguistic criteria into textbook evaluation can further align materials with students' capacities.

The prevalence of low-frequency and domain-specific terminology highlights the need for systematic academic vocabulary instruction in science classrooms. Effective strategies include morphological analysis, semantic mapping, contextualized use, and repeated exposure. Deep word knowledge, understanding roots, prefixes, and suffixes, supports both decoding and conceptual understanding more than rote memorization. High student agreement on difficult vocabulary also indicates that learner-judgment tasks can serve diagnostically, guiding scaffolding, informing material revision, and supporting data-driven instructional planning.

Since perceived linguistic competence predicts science achievement both directly and indirectly, instruction should intentionally enhance students' linguistic self-efficacy. Scaffolded reading tasks, guided modeling, gradual increases in text complexity, and structured mastery experiences can build confidence while supporting comprehension. The negative effects of perceived textbook complexity underscore the need for proactive scaffolding, including pre-teaching key terminology, modeling analytical reading strategies, segmenting complex sentences, and promoting collaborative discussion to distribute cognitive load. These strategies reduce linguistic strain without sacrificing disciplinary rigor.

Teaching should promote multiple forms of student engagement through approaches like inquiry-based learning, projects, and structured discussions, while also providing clear language support. Teachers should be trained in disciplinary literacy to help them teach the specific language features of subjects such as science, including vocabulary, sentence structure, and coherence. At the policy level, education systems should adopt more comprehensive measures of language complexity beyond basic readability formulas and encourage collaboration between language and subject-area teachers.

CHAPTER SIX

CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

6.1. Conclusions

The present study investigated the linguistic complexity of reading texts in the 7th-grade science textbook and the structural relationships among perceived linguistic competence, perceived textbook complexity, student engagement, and science achievement. By integrating learner-based judgments, computational indices, and structural equation modeling, it provides a comprehensive account of linguistic factors as both a cognitive demand and a motivational determinant in science learning. The conclusions are organized around key findings and their integrated implications.

The analysis of reading texts in the 7th-grade science textbook revealed substantial linguistic complexity. Between 62% and 78% of words were identified as complex by students at the ≥40% agreement threshold, with many reaching ≥70%, indicating that perceived complexity was systematically embedded in the reading texts. Computational measures supported these perceptions that lexical density ranged from 0.69 to 0.78, reflecting high informational compression typical of scientific discourse. The texts showed particularly dense structures, and high concentrations of technical vocabulary. Lexical sophistication indicated a large proportion of low-frequency words, while adjusted lexical diversity confirmed substantial variation independent of text length that make linguistic features complex.

Structural equation modeling showed that perceived linguistic competence, perceived textbook complexity, and multidimensional engagement jointly explained 73% of the variance in science achievement. Dimensions of perceived linguistic competence, with semantic competence emerging as the strongest predictor of both engagement and achievement. Although direct effects were modest, substantial indirect effects through engagement profiles indicate that linguistic confidence enhances achievement by promoting deeper involvement in learning. In contrast, perceived textbook complexity had strong negative direct and indirect effects via all engagement dimensions, with higher perceived complexity associated with lower engagement and achievement. Among engagement dimensions, behavioral engagement showed the strongest effect on achievement, indicating the central role of sustained participation.

The findings reveal a dynamic interplay among linguistic complexity, linguistic self-perception, engagement, and science achievement. Perceived linguistic competence enhances engagement and performance, whereas perceived textbook complexity reduces engagement and hinders achievement. These findings underscore that language is not merely a medium of instruction but a structural determinant of engagement and learning, emphasising the need for science education to address the linguistic demands through which disciplinary knowledge is conveyed.

6.2. Limitations of the Study

Although the study provides theoretically and empirically grounded insights into the relationships among perceived linguistic competence, textbook complexity, engagement, and science achievement, several limitations warrant caution. Key constructs were measured exclusively through self-report, which, despite their relevance to motivational theory, may introduce biases such as social desirability and acquiescence. The lack of objective measures, such as standardized tests, teacher evaluations, observational data, or verified linguistic indices, limits the validation of the findings.

The study's cross-sectional design limits causal inference. Although structural equation modeling tested theoretically specified pathways and explained substantial variance, the relationships remain correlational. Because engagement and perceived competence are dynamic and potentially reciprocal, longitudinal or experimental designs are needed to establish temporal order and clarify directionality.

The sample was limited to seventh-grade students in a specific Ethiopian English-medium context, restricting generalizability to other grades, linguistic populations, or educational systems. The study also did not comprehensively profile all instructional materials or include covariates like prior achievement or general academic self-concept. Future longitudinal, multi-method, and cross-contextual research with broader variable inclusion would strengthen causal inference and improve the applicability of the findings.

6.3. Recommendations

The findings indicate that textbook linguistic complexity, perceived linguistic competence, and multidimensional engagement are interrelated determinants of science achievement. Given linguistic analysis and the strong direct and indirect effects identified through structural equation modeling, recommendations should target multiple levels of the educational system, including curriculum design, classroom practice, teacher preparation, student support, and the policy at large.

6.3.1. Recommendations for textbook development and curriculum design

The analysis revealed high lexical density, advanced lexical sophistication, and multidimensional phonological, lexical, and semantic demands in 7th-grade science textbook, underscoring the need for systematic linguistic review in textbook development and selection. Curriculum designers should implement multidimensional complexity audits, including lexical density measures, frequency-based sophistication indices, cohesion analysis, and learner-based validation. The strong alignment between students' perceived complexity and computational indicators demonstrates that such tools can reliably identify linguistically demanding contents prior to classroom use.

Textbook authors should maintain scientific rigor while enhancing linguistic accessibility. The findings indicate that excessive nominalization, dense noun phrases, and clusters of low-frequency terms increase cognitive demand and reduce engagement. Authors should therefore distribute technical content across shorter units, embed contextual definitions at first use, and incorporate visual supports to aid comprehension. These adjustments preserve disciplinary integrity while reducing unnecessary linguistic complexity and cognitive strain.

Textbooks should incorporate built-in vocabulary scaffolding. Given the strong link between lexical sophistication and perceived complexity, supports such as glossaries, morphological analysis, highlighted key terms, and contextual practice should be embedded within chapters. This integrated approach ensures consistent support across contexts and reduces reliance on individual teacher adaptation.

6.3.2. Recommendations for classroom instruction

The structural equation modeling shows that perceived linguistic competence predicts science achievement both directly and through engagement, highlighting the need to integrate disciplinary literacy into science instruction. Teachers should explicitly support students in unpacking dense language, analyzing morphological components of technical terms, and paraphrasing abstract concepts. Language should be treated as a core component of science learning rather than a peripheral skill.

Given the significant negative effects of perceived textbook linguistic complexity on engagement, teachers should pre-teach high-impact, low-frequency vocabulary prior to reading activities. Introducing technical terms through contextual examples, visual supports, and interactive discussion reduces cognitive load during subsequent reading. Repeated retrieval and usage across lessons further consolidate lexical knowledge and enhance perceived competence.

Structured reading protocols are also essential. Teachers should implement guided reading strategies, think-aloud demonstrations, collaborative interpretation tasks, and systematic text chunking. Breaking complex passages into manageable units reduces perceived difficulty and prevents disengagement. These practices are particularly important because engagement dimensions were shown to mediate the relationship between linguistic perceptions and achievement. Classroom practices should intentionally foster cognitive, behavioral, emotional, and agentic engagement through inquiry-based learning, student questioning, and collaborative problem-solving, with concurrent linguistic scaffolding to prevent language barriers from limiting participation.

6.3.3. Recommendations for teacher education and professional development

The findings underscore the need for comprehensive teacher training in linguistic complexity awareness. Teacher education programs should incorporate modules on lexical density, lexical sophistication, cohesion patterns, and semantic compression in scientific texts. Educators must develop the ability to identify linguistic barriers embedded in instructional materials and to design appropriate scaffolding strategies.

Professional development should focus on integrated language-and-content pedagogy, demonstrating how to embed vocabulary instruction, scaffold academic discourse, and support comprehension of complex sentences, enabling teachers to enhance both linguistic competence and engagement.

4.3.4. Recommendations for student support systems

The significant role of perceived linguistic competence in predicting science achievement highlights the importance of strengthening students' linguistic self-efficacy. Schools should design structured mastery experiences that progressively increase text complexity while providing guided support. Positive feedback emphasizing linguistic growth can reinforce students' perceptions of competence and foster sustained engagement.

Early diagnostic screening of academic vocabulary knowledge and text comprehension skills is also recommended. Students demonstrating low linguistic competence or high perceived difficulty should receive targeted interventions before patterns of disengagement emerge. Such interventions may include small-group vocabulary workshops, peer tutoring, or supplemental reading support programs focused on scientific texts.

4.3.5. Recommendations for educational policy and system-level reform

At the policy level, educational authorities should incorporate linguistic complexity standards into textbook evaluation frameworks. Rather than relying exclusively on traditional readability formulas, evaluation criteria should include lexical density thresholds, frequency distribution analysis, and cohesion metrics. Establishing such standards ensures that textbook language aligns with developmental expectations.

Policymakers should encourage interdisciplinary collaboration in curriculum design, involving science educators, applied linguists, literacy specialists, and cognitive psychologists in textbook development and instructional planning. The findings show that science learning is inherently language-dependent, necessitating expertise across domains. Funding should also support intervention-based research and longitudinal studies to evaluate how targeted linguistic scaffolding influences engagement and achievement.

This study emphasised the need to reconceptualize science education as inherently language-intensive, with linguistic complexity shaping cognitive processing, engagement, and achievement. Reforms focused only on conceptual content, without addressing linguistic accessibility, are unlikely to improve outcomes. Effective improvement requires coordinated attention to textbook design, teacher expertise, and policy to align linguistic demands with learners' capacities and provide systematic scaffolding. Equitable access to science depends on equitable access to the language through which it is constructed and communicated.

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APPENDICES

Appendix A: Questionnaires (English Version)

Bahir Dar University

College of Education, School of Educational Sciences

Department of Psychology

Dear Students,

My name is Henos Ejigu Wondimagegn. I am a PhD student in a program of Educational Psychology at Bahir Dar University and undertaking a PhD dissertation study as a requirement for the fulfilment of the program. The purpose of this questionnaires is to examine **effects of students perceived linguistic competence and textbook linguistic complexity on science achievement via engagement profiles among 7th-grade classes**. The sources of data for this study are students in public and private middle schools under Bahir Dar City Administration.

Most of the data for this research is collected through a questionnaire, and the source of the data is from the 7th grade students in public and private primary schools in Bahrdar city administration. Dear participant, the participation in this study is based on the personal willingness in line with the consent. There will be neither special benefit nor any harm for participating in this study. Therefore, the study participants may withdraw from the study at any time; your responses will be kept completely confidential. The questionnaire consists of four parts, the first part is about personal background information; the second part is about measures of students perceived linguistic competence; the third part is about students perceived textbook linguistic complexity; and the fourth part is about measures of students' engagement profiles. It takes about 40 to 45 minutes to complete this questionnaire.

Dear participant, the data collected through this questionnaire will be used for the research purpose only. You are requested to feel free to ask anything about the overall procedures of the study by calling to 0918199797 or by mailing to henosjigu@gmail.com. If you have read the consent form and agree to participate in this study, please confirm your agreement by signing the space below.

Signature: - _______________ Date: - ______________________________

Thank you for your cooperation in filling this questionnaire!

Part One: Participants' Background Information

Instruction: Please write your responses to the questions listed below that relate to your personal information in the space provided.

1. Sex: - (Male = 1; Female = 2) _________________

2. Age: ________________

3. School: - (Private = 1; Public = 2) __________________

Part two: Questionnaires

Questionnaire One: Student's Perceived Linguistic Competence Scale (PLCS)

The items inside the following box are measuring your perceived linguistic competence. The numbers correspondence to items in the right side of the table represents 1 = not true at all, 2 = not true, 3= somewhat true, 4= true, and 5= very true. Hence, after carefully reading each item, circle the number of your choice against each statement.

No.	Items	Responses				
	A) Perceived Phonological Linguistic Competence (PPLC)					
1	I am able to correctly pronounce terminologies in the general science textbook.	1	2	3	4	5
2	I can understand well when science teachers teach science lessons in the English language.	1	2	3	4	5
3	I always find them difficult to pronounce terminologies in the general science textbook.	1	2	3	4	5
4	I am aware of the correct stress patterns of terminologies in the general science textbook.	1	2	3	4	5
5	I am able to correct my pronunciation of terminologies in the general science textbook when I realize I have said them incorrectly.	1	2	3	4	5
6	It is difficult for me to distinguish the meanings of similar-sounding terminologies in the general science textbook.	1	2	3	4	5
7	I always ask my science teachers for help when I find it difficult to pronounce scientific terms correctly in class.	1	2	3	4	5

	B) **Perceived Lexical Linguistic Competence (PLLC)**	**Responses**				
8	I am able to understand terminologies in the general science textbook.	1	2	3	4	5
9	I always encounter unfamiliar terminologies while reading the general science textbook.	1	2	3	4	5
10	I always struggle to understand terminologies formed with prefixes or suffixes in the general science textbook.	1	2	3	4	5
11	The lexical richness of vocabularies in the general science textbook are confusing.	1	2	3	4	5
12	I am not able to understand science texts due to unfamiliar terminologies.	1	2	3	4	5
13	I am not able to recognize terminologies in the general science textbook due to their multiple meanings.	1	2	3	4	5
14	I have difficulty memorizing and retaining the words found in the science textbook.	1	2	3	4	5
15	I am able to recognize antonyms for terminologies to a deeper understanding of contrasts and distinctions in scientific concepts.	1	2	3	4	5
16	I get difficult to understand and use jargon words in the general science textbook.	1	2	3	4	5
	C) **Perceived Semantics Linguistic Competence (PSLC)**	**Responses**				
17	The meaning of terminologies in the general science textbook is clear and easy to understand.	1	2	3	4	5
18	I am able to recognize the contextual meaning of terminologies in the general science textbook.	1	2	3	4	5
19	I always find terminologies in the general science textbook ambiguous or open to multiple interpretation.	1	2	3	4	5
20	I am able to use context clues to understand unfamiliar scientific terminologies in the general science textbook.	1	2	3	4	5
21	I feel difficult to infer the meanings of scientific terminologies in the textbook from context.	1	2	3	4	5

Questionnaire Two: Students' Perceived Textbook Linguistic Complexity Questionnaire (PTLCQ)

The following questions are about your perception of the general science textbook linguistic complexity. The numbers correspondence to items in the right side of the table represents 1 =

not true at all, 2 = not true, 3 = somewhat true, 4 = true, and 5 = very true. Hence, after carefully reading each item, circle the number of your choice against each statement.

No.	Items	Responses				
1	The reading texts in the science textbook contain difficult terminologies to understand.	1	2	3	4	5
2	I always face frequent technical words that make the reading texts hard to understand.	1	2	3	4	5
3	I always encounter abstract words in the reading texts of science textbook difficult to understand.	1	2	3	4	5
4	Reading texts found in the science textbook contain words that are difficult to pronounce.	1	2	3	4	5
5	I often encounter unfamiliar words in the reading texts of the science textbook.	1	2	3	4	5
6	I always found words in the reading texts of science textbook difficult to recall.	1	2	3	4	5
7	I always encounter meaning of the words in the reading texts difficult to understand.	1	2	3	4	5
8	7th-grade Science textbook contains complex concepts that are complex to understand.	1	2	3	4	5
9	The meanings of words in the reading texts of science textbook are difficult to understand.	1	2	3	4	5

Questionnaire Three: Students' Engagement in Learning Science (SELS)

The items inside the following box are measuring the extent to which you engage in science learning. The numbers correspondence to items in the right side of the table represents 1=strongly disagree, 2=disagree 3=undecided, 4= agree, and 5= strongly agree. Hence, after carefully reading each item, circle the number of your choice against each statement.

No.	Items					
	A) Cognitive Engagement (COG)					
1	I think deeply about the scientific concepts discussed in class.	1	2	3	4	5
2	When I read the general science textbook, I try to ask myself questions to deepen my understanding.	1	2	3	4	5
3	I actively think about the concepts and information presented in the general science textbook while reading it.	1	2	3	4	5

4	I get focused while doing science tasks.	1	2	3	4	5
5	I try to relate the concepts in the general science textbook to real-life situations.	1	2	3	4	5
6	I recall scientific terminologies when I seat on science exams.	1	2	3	4	5
7	I try to understand examples given to illustrate scientific terminologies and concepts in the general science textbook.	1	2	3	4	5
8	I lose attention while doing science tasks due to word difficulties.	1	2	3	4	5
9	I understand general science texts better.	1	2	3	4	5
10	I retain scientific terminologies and concepts long.	1	2	3	4	5
11	I try to focus to understand contents in the general science textbook.	1	2	3	4	5
	B) Behavioral Engagement (BEH)	**Responses**				
12	I always participate in discussions during science learning.	1	2	3	4	5
13	I try hard to do well in science learning activities.	1	2	3	4	5
14	In science class, I listen carefully to my teachers and classmates.	1	2	3	4	5
15	I actively read the general science textbook to understand every detail of the content.	1	2	3	4	5
16	I try to collaborate with my peers to science-related activities.	1	2	3	4	5
17	I try to make re-reading texts of the science textbook to better understand the content.	1	2	3	4	5
18	I persist trying complex science problems until I understand.	1	2	3	4	5
19	I spend a lot of time reading the general science textbook during each study session.	1	2	3	4	5
20	I try to ask questions during science lessons when I don’t understand concepts.	1	2	3	4	5
	C) Emotional Engagement (EMOT)	**Responses**				
21	I enjoy learning grade 7 General Science in English.	1	2	3	4	5
22	I always feel happy reading the 7th grade general science textbook.	1	2	3	4	5
23	I enjoy doing science-related activities.	1	2	3	4	5
24	I enjoy interpreting complex terminologies and concepts in the general science textbook.	1	2	3	4	5
25	I feel interested doing science activities in the textbook.	1	2	3	4	5
26	I feel a sense of accomplishment when I complete reading the general science textbook.	1	2	3	4	5
27	I feel very happy when I read the science textbook for a long time.	1	2	3	4	5

	D) Agentic Engagement (AGNT)	Responses				
28	I try to reflect my own ideas in science learning.	1	2	3	4	5
29	I try to use my own examples to understand scientific terminologies in the textbook.	1	2	3	4	5
30	I try to plan out my own approach to complete science activities in the textbook.	1	2	3	4	5
31	I pause and reflect on challenging science concepts in the textbook before moving forward.	1	2	3	4	5
32	I try different strategies until I understand concepts in the general science textbook.	1	2	3	4	5
33	I try to control over my own comprehension of science concepts in the textbook.	1	2	3	4	5

Thank you very much for your participation in the study!!!

Appendix B: መጠይቆች (የአማርኛው ትርጉም)

ባህር ዳር ዩኒቨርስቲ

የትምህርት ኮሌጅ ትምህርት ሳይንስ ትምህርት ቤት

የስነልቦና ትምህርት ክፍል

ውድ ተማሪዎች፡-

ሄኖስ እጅጉ ወንድማገኝ እባላለሁ። በባህር ዳር ዩኒቨርስቲ፤ በትምህርት ኮሌጅ፤ የትምህርት ሳይንስ ትምህርት ቤት፤ የስነልቦና ትምህርት ክፍል የ3ኛ ዲግሪ ተማሪ ነኝ። በአሁኑ ሰዓት በትምህርት ሳይኮሎጂ የዶክትሬት ዲግሪ ማሟያ የሚሆን የጥናትና ምርምር ስራየን እየሰራሁ ሲሆን የዚህ ጥናት ዋና ዓለማም የ 7ተኛ ክፍል **ተማሪዎች ስለራሳቸው የእንግሊዝኛ ቋንቋ ብቃት እና በሳይንስ መማሪያ መጽሀፍ ዉስጥ ስለሚገኙ የቋንቋ ባህሪያት ዉስብስብነት ያላቸው ግንዛቤ/አመለካከት በሳይንስ ትምህር ሁለንተናዊ ተሳትፏቸው እና የሳይንስ ትምህርት ዉጤታቸው ላይ ያለውን ተጽእኖ** ለማጥናት ነው፡፡

ለዚህ ጥናት የሚሆን አብዛኛው መረጃ የሚሰበሰበው በመጠይቅ ሲሆን የመረጃው ምንጭም በባህርዳር ከተማ አስተዳደር ውስጥ በሚገኙ የመንግስትና የግል አንደኛ ደረጃ ትምህርት ቤቶች ዉስጥ ከ7ኛ ክፍል ተማሪዎች ይሆናል። ተሳትፎው ሙሉ በሙሉ በፈቃደኝነት ላይ የተመሰረተ ሲሆን በዚህ ጥናት የሚሳተፉ ተማሪዎችም ከተሳታፊነታቸው ጋር በተያያዘ ምንም አይነት ጉዳት አይደርስባቸውም። በመሆኑም የጥናቱ ተሳታፊወች በማንኛውም ጊዜ ከጥናቱ እራሳቸውን ሊያገሉ ይችላሉ፤ የሚሰጡትም ምላሽ ሙሉ በሙሉ በሚስጥር ይያዛል። መጠይቁ ሁለት ክፍሎችን የያዘ ሲሆን የመጀመሪያው ክፍል ስለግላዊ መረጃ የሚጠይቁ ጥያቄዎችን፤ ሁለተኛው ክፍል ደግሞ ተማሪዎች ስለራሳቸው የእንግሊዝኛ ቋንቋ ብቃት ያላቸውን ግንዛቤ፤

በሳይንስ መማሪያ መጽሃፍ ዉስጥ ስለሚገኙ የቋንቋ ባህሪያት ክብደት ያላቸውን ሃሳብ፤ እና የተማሪዎች የሳይንስ ሁለንተናዊ ተሳትፎ ምን እንደሚመስል የሚለኩ ጥያቄዎችን የያዘ ነው። መጠይቁን ለመሙላት በአማካኝ 40 ደቂቃ ይወስዳል፡፡

ውድ ተማሪዎች፤ በዚህ መጠይቅ የሚሰበሰበው መረጃ ለትምህርታዊ አላማ ብቻ የሚውል ይሆናል። ስለ ጥናቱ እና የጥናቱን አጠቃላይ አካሄድ በተመለከተ ጥያቄ ካለዎት በስልክ ቁጥር **0918199797** ወይም በኢሜል አድራሻ **henosjigu@gmail.com** አማካኝነት አጥኝዉን ማነጋገር ይቻላል፡፡ የስምምነት ወረቀቱን አንብበው በዚህ ጥናት ለመሳተፍ ከተስማሙ እባክዎ ከዚህ በታች ባለው ክፍት ቦታ ላይ በመፈረም ስምምነትዎን ያረጋግጡ።

ፊርማ፡- ______________________ **ቀን፡-** ______________________________________

በዚህ ጥናት ላይ ለመሳተፍ ፈቃደኛ ስለሆኑ ከወዲሁ ከልንብ አመሰግናለሁ!

ክፍል አንድ፡ የጥናቱ ተሳታፊወች ግላዊ መረጃ

መመሪያ፡ እባክዎ ከዚህ በታች ለተዘረዘሩት ግላዊ መረጃን የተመለከቱ ጥያቂወች ምላሽዎን በተሰጠው ክፍት ቦታ ላይ ይጻፉ።

1. **ጾታ፡- (1 = ወንድ እና 2 = ሴት) _______________**
2. **የሚማሩበት ትምህርት ቤት (የግል =1 ፤ የመንግስት = 2) ፡- _______________**
3. **እድሜ፡- ______________**

መጠይቅ አንድ፡- ተማሪዎች ስለራሳቸው የቋንቋ ብቃት ያላቸው አመለካከት

የሚከተሉት ጥያቄወች ስለራሳችሁ የቋንቋ ብቃት ያላችሁን ግንዛቤ/አመለካከት በተመለከተ የቀረቡ ናቸው። እባክወ እነዚህን ጥያቄወች በአግባቡ አንብበው ምላሽዎ **"ፈጽሞ እዉነት አይደለም"** ከሆነ **"1" ን**፤ **"እዉነት አይደለም"** ከሆነ **"2" ን**፤ **"በመጠኑ እዉነት ነው"** ከሆነ **"3" ን**፤ **"እዉነት ነው"** ከሆነ **"4" ን** እና **"በጣም እዉነት ነው"** ከሆነ ደግሞ **"5" ን** ያክቡ።

ተ.ቁ	**ተማሪዎች ስለራሳቸው የቋንቋ ብቃት ያላቸውን አመለካከት የተመለከቱ ጥያቄዎች**	**አማራጮች**				
ሀ) ቢቃላት ድምጽ እና አጠራር ዙሪያ ያለወት የቋንቋ ብቃት						
1	በሳይንስ መማሪያ መጽሐፍ ውስጥ የሚገኙ ቃላትን በትክክል ማንበብ/መጥራት እችላለሉ።	1	2	3	4	5
2	የሳይንስ መምህሮቸ ትምህርቱን በእንግሊዝኛ ቋንቋ በሚያስተምሩበት ጊዜ በደንብ መስማት እችላለሁ።	1	2	3	4	5
3	በሳይንስ መማሪያ መጽሐፍ ውስጥ የሚገኙ ቃላትን በትክክል በድምጽ መጥራት ሁልጊዜ እቸገራለሁ።	1	2	3	4	5
4	በሳይንስ መማሪያ መጽሀፍ ውስጥ የሚገኙ ቃላትን ትክክለኛ የአነባበብ ስልት (word stress) በሚገባ አዉቃለሁ።	1	2	3	4	5

5	በሳይንስ መማሪያ መጽሀፍ ውስጥ የሚገኙ ቃላትን በትክክል እንዳልጠራኋቸው ስገነዘብ እንደገና እንደገና ማስተካከል እችላለሁ።	1	2	3	4	5
6	በሳይንስ መማሪያ መጽሐፍ ውስጥ ተመሳሳይ ድምጽ ባላቸው ቃላት መካከል ያለን የትርጉም ልዩነት መለየት ያስቸግረኛል።	1	2	3	4	5
7	በክፍል ውስጥ ሳይንሳዊ ቃላትን በትክክል መጥራት ከባድ ሲሆንብኝ ሁልጊዜ ከሳይንስ መምህሮቼ እገዛ እጠይቃለሁ።	1	2	3	4	5
	ለ) ያልተለመዱ እና በየቀኑ የማንጠቀምባቸውን ቃላት ለመረዳት ያለወት ብቃት					
8	በሳይንስ መማሪያ መጽሀፍ ውስጥ የሚገኙ ቃላትን መረዳት እችላለሁ።	1	2	3	4	5
9	የሳይንስ መማሪያ መጽሃፍን በማነብበት ጊዜ ሁሌም የማላውቃቸው ቃላት ያጋጥሙኛል።					
10	በሳይንስ መማሪያ መጽሀፍ ውስጥ ከቅድመ ቅጥያ ወይም ድህረ ቅጥያ ጋር የተመሰረቱ ቃላትን መረዳት ሁልጊዜ እቸገራለሁ።					
11	በሳይንስ መማሪያ መጽሐፍ ውስጥ የሚገኙ የቃላት እርቢወችን መረዳት እቸገራለሁ።					
12	በማላውቃቸው ቃላት ምክንያት የሳይንስ ጽሑፎችን መረዳት እቸገራለሁ።					
13	ብዙ ትርጉም የያዙ ከመሆናቸው የተነሳ በሳይንስ መማሪያ መጽሀፍ የሚገኙ ቃላትን አንዱን ካንዱ መለየት ይከብደኛል።					
14	በሳይንስ መማሪያ መጽሀፍ የሚገኙ ቃላትን በአእምሮየ ማስታወስ እና ይዞ ማቆየት እቸገራለሁ።	1	2	3	4	5
15	የሳይንስ ፅንሰ-ሀሳቦችን ተመሳሳይነት እና ልዩነቶች በጥልቀት ለመረዳት የቃላትን ተቃራኒ ትርጉም በሚገባ አዉቃለሁ።	1	2	3	4	5
16	የሳይንስ ጽንሰ ሃሳቦችን ለመረዳት ብቻ የሚዉሉ ሙያዊ ቃላትን መረዳት እና መጠቀም እቸገራለሁ።	1	2	3	4	5
	ሐ) የቃላትን ረቂቅነት፤ቴክኒካዊነት እና ጽንሰሃሳባቸውን ለመረዳት ያለወት ብቃት					
17	በሳይንስ መማሪያ መጽሐፍ ውስጥ የሚገኙ ቃላትን ትርጉማቸውን ለመረዳት ግልጽ እና ቀላል ነው።	1	2	3	4	5
18	በሳይንስ መማሪያ መጽሃፍ ዉስጥ የሚገኙ ቃላትን አውዳዊ ትርጉም መረዳት እና መጠቀም እቸገራለሁ።	1	2	3	4	5
19	በሳይንስ መማሪያ መጽሐፍ ውስጥ የሚገኙ ቃላት ሁልጊዜ አሻሚ ወይም ለብዙ ትርጓሜዎች ክፍት ሆነው አገኛቸዋለሁ።	1	2	3	4	5
20	በሳይንስ መማሪያ መጽሀፍ ውስጥ የማላውቃቸውን ቃላት ለመረዳት አውዳዊ ፍችን በአመላካችነት እጠቀማለሁ።	1	2	3	4	5
21	የሳይንስ ቃላትን ትርጉም በተሰጠው ዐውደ-ጽሑፉ መሰረት መረዳት እንደምቸገር ይሰማኛል።	1	2	3	4	5

<u>መጠይቅ ሁለት፡- ተማሪዎች ስለሳይንስ መማሪያ መጽሃፍ የቋንቋ ዉስብስብነት ያላቸው ግንዛቤ/አመለካከት</u>

የሚከተሉት ጥያቄወች እናንተ በሳይንስ መማሪያ መጽሃፍ ዉስጥ ባሉ የቋንቋ ባህሪያት ክብደት ያላቸሁን አመለካከት በተመለከተ የቀረቡ ናቸው። እባክወ እነዚህን ጥያቄወች በአግባቡ አንብበው ምላሸዎ **"ፈጽሞ እዉነት አይደለም"** ከሆነ **"1"ን**፤ **"እዉነት አይደለም"** ከሆነ **"2"ን**፤ **"በመጠኑ እዉነት ነው"** ከሆነ **"3"ን**፤ **"እዉነት ነው"** ከሆነ **"4"ን** እና **"በጣም እዉነት ነው"** ከሆነ ደግሞ **"5"ን** ያክቡ።

ተ.ቁ	**በሳይንስ መማሪያ መጽሃፍ ዉስጥ በሚገኙ የቋንቋ ዉስብስብነት ያለወት ግንዛቤ/አመለካከት**	**አማራጮች**

1	በሳይንስ መማሪያ መጽሃፍ ዉስጥ የሚገኙ ምንባቦች ትርጉማቸዉን ለመረዳት ከባድ የሆኑ ቃላትን ይዘዋል።	1	2	3	4	5
2	በሳይንስ መጽሃፍ ውስጥ ብዙ ቴክኒካል ቃላቶችን ስለሚያጋጥሙኝ ምንባቦችን መረዳት ይከብደኛል።	1	2	3	4	5
3	በሳይንስ መማሪያ መጽሐፉ ባሉ ምንባቦች ውስጥ ሁልጊዜ ለመረዳት አስቸጋሪ የሆኑ ዉስብስብ ቃላትን እገናኛለሁ።	1	2	3	4	5
4	በሳይንስ መማሪያ መጽሐፍ ዉስጥ የሚገኙ ምንባቦች ለመጥራት/ለማንበብ አስቸጋሪ የሆኑ ቃላትን ይዘዋል።	1	2	3	4	5
5	በሳይንስ መማሪያ መጽሐፉ ባሉ ምንባቦች ውስጥ ብዙ ጊዜ ያልተለመዱ ቃላትን እገናኛለሁ።	1	2	3	4	5
6	በሳይንስ መማሪያ መጽሐፉ ባሉ ምንባቦች ውስጥ ያሉ ቃላትን ሁልጊዜም ማስታወስ ይከብደኛል።	1	2	3	4	5
7	በሳይንስ መማሪያ መጽሐፉ ባሉ ምንባቦች ውስጥ ያሉ ቃላትን ትርጉም ሁልጊዜም መረዳት አስቸጋሪ ይሆኑብኛል።	1	2	3	4	5
8	የሳይንስ መማሪያ መጽሐፋችን ለመረዳት ከባድ የሆኑ ጽንሰ-ሀሳቦችን ይዟል።	1	2	3	4	5
9	በሳይንስ መማሪያ መጽሐፍ ባሉ ምንባቦች ዉስጥ የሚገኙ የቃላት ትርጉሞችን መረዳት አስቸጋሪ ነው።	1	2	3	4	5

<u>መጠይቅ ሶስት፡- የተማሪዎች ለሳይንስ ትምህርት ያላቸው ሁለንተናዊ ተሳትፎ</u>

የሚከተሉት ጥያቄወች የተማሪዎችን የሳይንስ ትምህርት ሁለንተናዊ ተሳትፎን በተመለከተ የቀረቡ ናቸው። እባክዎ እነዚህን ጥያቄወች በአግባቡ አንብበው ምላሽዎ **"በጣም አልስማማም"** ከሆነ **"1"ን"፤ አልስማማም"** ከሆነ **"2"ን**፤ **"መወሰን ያቅተኛል"** ከሆነ **"3"ን**፤ **"እስማማለሁ"** ከሆነ **"4"ን** እና **"በጣም እስማማለሁ"** ከሆነ ደግሞ **"5"ን** ያክቡ።

ተ.ቁ	ተማሪዎች ለሳይንስ ትምህርት ያላቸውን ሁለንተናዊ ተሳትፎን የተመለከቱ ጥያቄዎች	አማራጮች				
	ሀ. ግንዛቤያዊ ተሳትፎ (Cognitive Engagement)					
1	በክፍል ውስጥ ስለምንወያይባቸው ሳይንሳዊ ጽንሰ-ሐሳቦች በጥልቀት አስባለሁ።	1	2	3	4	5
2	የሳይንስ መማሪያ መጽሃፍን በማነብበት ጊዜ ግንዛቤዬን ለማስፋት ስል ራሴን ጥያቄዎችን እጠይቃለሁ።	1	2	3	4	5
3	የሳይንስ መማሪያ መጽሃፍን በማነብበት ጊዜ በመጽሃፉ ውስጥ ስለቀረቡት ጽንሰ-ሐሳቦች እና መረጃዎች በንቃት አስባለሁ።	1	2	3	4	5
4	ሳይንስ ትምህርትን በማማርበት እና የሳይንስ ተግባራትን በማከናዉንበት ጊዜ ትኩረት አጣለሁ።	1	2	3	4	5
5	በሳይንስ መማሪያ መጽሀፍ ውስጥ ያሉትን ጽንሰሃሳቦች ከእውነተኛ የህይወት ተሞክሮወች ጋር ለማገናኘት እሞክራለሁ።	1	2	3	4	5
6	የሳይንስ ትምህርትን በምፈተንበት ጊዜ ሳይንሳዊ ቃላትን በደንብ አስታውሳለሁ።	1	2	3	4	5
7	በሳይንስ መጽሃፍ ዉስት ያሉ ቃላትን እና ጽንሰ-ሐሳቦችን ለማብራራት የሚሰጡ ምሳሌዎችን ለመረዳት እሞክራለሁ።	1	2	3	4	5
8	የሳይንስ ትምህርት ስራወችን በማከናዉንበት ጊዜ በቃላት ዉስብስብነት ምክንያት አትኩሮቴን አጣለሁ።	1	2	3	4	5
9	በሳይንስ መማሪያ መጽሃፍ ዉስት ያሉ ምንባቦችን በደንብ እረዳለሁ።	1	2	3	4	5

10	ሳይንሳዊ ቃላትን እና ጽንሰ-ሀሳቦችን በአእምሮየ ለረጅም ጊዜ አቆያለሁ።	1	2	3	4	5
11	በሳይንስ መማሪያ መጽሃፍ ዉስጥ የሚገኙ ይዘቶችን ለመረዳት አተኩሮት አደርጋለሁ።	1	2	3	4	5
	ለ. ባህሪያዊ ተሳትፎ (Behavioral Engagement)					
12	ሳይንስን ለመማር በሚደረጉ ዉይይቶች ሁልጊዜም እሳተፋለሁ።	1	2	3	4	5
13	የሳይንስ ትምህርት ተግባራትን ጠንክሬ አከናዉናለሁ።	1	2	3	4	5
14	በሳይንስ ክፍለ ጊዜ አስተማሪዎቼን እና የክፍል ጓደኞቼን በጥሞና አዳምጣለሁ።	1	2	3	4	5
15	የእያንዳንዱን የሳይንስ ትምህርት ይዘትን ዝርዝር ሁኔታ ለመረዳት መማሪያ መጽሃፍን በንቃት አነባለሁ።	1	2	3	4	5
16	የሳይንስ ትምህርት ተግባራትን ከእኩዮቼ ጋር አከናዉናለሁ።	1	2	3	4	5
17	የትምህርት ይዘቱን የበለጠ ለመረዳት በሳይንስ መማሪያ መጽሃፍ ዉስጥ የሚገኙ ምንባቦችን በመደጋገም አነባለሁ።	1	2	3	4	5
18	ውስብስብ የሆኑ የሳይንስ ስራወችን እስከረዳ ድረስ ደጋግሞ መስራት አላቆምም።	1	2	3	4	5
19	በእያንዳንዱ የጥናት ክፍለ ጊዜ የሳይንስ መማሪያ መጽሐፍን በማንበብ ብዙ ጊዜ አሳልፋለሁ።	1	2	3	4	5
20	በሳይንስ ክፍለ ጊዜ የሳይንስ ጽንሰ-ሐሳቦች በማይገቡኝ ጊዜ ጥያቄዎችን እጠይቃለሁ።	1	2	3	4	5
	ሐ. ስሜታዊ ተሳትፎ (Emotional Engagement)					
21	የሰባተኛ ክፍል ሳይንስ ትምህርትን በእንግሊዘኛ መማር ያስደስተኛል።	1	2	3	4	5
22	የሰባተኛ ክፍል ሳይንስ መማሪያ መጽሃፍን ሳነብ ሁሌም ደስታ ይሰማኛል።	1	2	3	4	5
23	ሳይንስ ነክ ስራወች ላይ መሳተፍ ደስታ ይሰጠኛል።	1	2	3	4	5
24	በሳይንስ መጽሃፍ ዉስጥ የሚገኙ ውስብስብ ሳይንሳዊ ቃላትን እና ጽንሰ-ሐሳቦችን መተርጎም ያስጠላኛል።	1	2	3	4	5
25	በሳይንስ መማሪያ መጽሃፍ ዉስጥ ያሉ ተግባራትን ማከናወን ያሰለቸኛል።	1	2	3	4	5
26	የሳይንስ መማሪያ መጽሃፍን አንብቤ ስጨርስ የስኬታማነት ስሜት ይሰማኛል።	1	2	3	4	5
27	የሳይንስ መማሪያ መጽሐፍን እያነበብኩ ረጅም ጊዜ ማሳለፍ ያስደስተኛል።	1	2	3	4	5
	መ. ነገሮችን በራስ የማድረግ/የማከናወን ተሳትፎ (Agentic Engagement)					
28	ሳይንስ ትምህርትን ስማር የራሴን ሃሳቦች ለማንፀባረቅ እሞክራለሁ።	1	2	3	4	5
29	የሳይንስ መማሪያ መጽሃፍን በማነብበት ጊዜ ፅንሰ-ሀሳቦችን ለመረዳት እንዲያግዘኝ የራሴን ምሳሌዎች እጠቀማለሁ።	1	2	3	4	5
30	በሳይንስ መማሪያ መጽሃፍ ዉስጥ ያሉ ተግባራትን ለማጠናቀቅ የምጠቀማቸውን ዘዴዎች አቅዳለሁ።	1	2	3	4	5
31	የሳይንስ መማሪያ መጽሃፍን በማነብበት ጊዜ ከባድ የሆኑ የሳይንስ ፅንሰ-ሀሳቦች ሲያጋጥሙኝ ማንበብ ከመቀጠሌ በፊት ቆም ብዬ ስለጉዳዩ አሰላስላለሁ።	1	2	3	4	5
32	በሳይንስ መማሪያ መጽሃፍ ዉስጥ ያሉ ቃላትን ወይም ጽንሰሃሳቦችን እስከረዳ/እስኪገባኝ ድረስ የተለያዩ ስልቶችን እጠቀማለሁ።	1	2	3	4	5
33	በሳይንስ መማሪያ መጽሃፍ ዉስጥ ያሉ ፅንሰ-ሀሳቦችን መረዳት መቻል እና አለመቻሌን ለመቆጣጠር እሞክራለሁ።	1	2	3	4	5

ስለትብብራችሁ እጅግ እናመሰግናለን!

Appendix C: Linguistic Complexity Judgement Task (For Textbook Linguistic Complexity Analysis)

Instruction

Dear participant student, here are four reading texts randomly drawn from your 7th-grade General Science Textbook. After you carefully read through these reading texts, please put a ☑ mark on a box against each linguistic feature in the table that follows the reading texts if you find the word complex either in phonology (difficult to pronounce due to length, syllables, or sounds), lexical (rare or unfamiliar and technical words or low-frequency vocabulary), semantic (words that are abstract or conceptually difficult to understand), or in combination (i.e., if you find the word complex either in *phonology + lexical then put a tick mark on both phonological and lexical*, in *phonology + semantic then put a tick mark on phonological and semantic*, in *lexical + semantic then put a tick mark on lexical and semantic*, or in *phonology + lexical +semantic then put a tick mark on all linguistic features*). Thank you for your participation.

Thank you very much for your participation in the study.

ትዕዛዝ፡

ውድ የዚህ ጥናት ተሳታፊ ተማሪ፣ የሚከተሉት አራት ምንባቦች በሎተሪ መንገር ከሰባተኛ ክፍል የሳይንስ መማሪያ መጽሀፋችሁ ዉስጥ የተመረጡ ናቸው። እባክወ ምንባቦችን በጥንቃቄ ካነበቧቸው በኋላ ቀጥለው በተሰጡት ሰንጠረዦች ውስጥ ያሉ ቃላቶችን ውስብስብ ሆነው ካገኟቸው በእያንዳንዱ የቋንቋ ባህሪያት ትይዩ ላይ ማለትም በድምፅ (ለመጥራት የሚከብዱ ቃላት ሲሆኑብዎ) ፣ በቃሉ ክብደት (አልፎ አልፎ ወይም ያልተለመዱ ቃላት ሲሆኑብዎ) ፣ የቃላት ትርጓሜ (ቃላቶቹ ረቂቅ ወይም ለመረዳት አስቸጋሪ ሲሆኑብዎ) የ ☑ ምልክት ያድርጉበት። የ ☑ ምልክት በሚያደርጉበት ጊዜ ቃላቱ ባንዱ ብቻ ከባድ ሆኖ ካገኙት አንዱ ላይ ብቻ ምልክቱን ማድረግ፤ ወይም ሁለቱ ብቻ ከከበደዎ ሁለቱም ላይ ምልክቱን ማስቀመጥ፤ ወይም ደግሞ ሶስቱም ላይ ከከበደዎ ሁሉም ላይ ቲክ ማድረግ ትችላላችሁ። ቃላቱ ለእርስዎ በሶስቱም የቋንቋ ባህሪያቶች ከባድ ሆኖ ካላገኙት ምንም የ ☑ ምልክት አታስቀምጡበት።

በጥናቱ ለመሳተፍ ፈቃደኛ ስለሆኑልን ከልብ እናመሰግናለን!

Reading Text One: Unicellular and multicellular organisms

A unicellular organism is an organism that consists of a single cell. That's all life processes such as reproduction, feeding, digestion, and excretion occur in one cell. Amoeba, paramecium, and all protozoa are examples of unicellular organisms. On the other hand, multicellular organisms are composed of many cells. All the cells work in coordination in multicellular organism. Plants, animals including humans, and most fungi are examples of multicellular organisms.

Reading Text Two: Seedless Plants

Plants that reproduce without seeds are called seedless plants. Bryophytes and ferns are seedless plants. Bryophytes are a group of small, simple, green land dwelling plants of which a few are aquatic. Bryophytes contain three groups: Liverworts, hornworts and mosses. Bryophytes reproduce by spores rather than flowers or seeds. They have a root-like, stem-like and leaf-like structure (no true root, stem or leaves). Mosses and liverworts are small, simple plants usually found in moist locations. You may find mosses around your house even the walls if the area is moist. Pteridophytes are seedless plants that have root, stem and leaves. They mainly grow well in moist and shady places. Most pteridophytes have vascular tissues to transport food (phloem) and water (xylem). Pteridophytes do not have seeds or flowers either, instead they reproduce by spores. Ferns are examples of pteridophytes. The leaves of ferns are often called fronds. If you look underneath a fern frond, you may see small patches that contain the spores. Not every frond has spores under it. Ferns have an underground stem called a rhizome from which the fronds develop.

Reading Text Three: Kingdom Protista

Kingdom Protista is a diverse group of unicellular eukaryotic organisms that are not plants, fungi, or animals. Protists have nucleus, mitochondria, and other organelles. Some have chloroplasts and can photosynthesize. They may reproduce sexually, asexually, or both. They occur in many environments, including water, soil, and inside of other organisms (parasites). The major groups of protists are protozoa and microscopic algae. Protozoa are single- celled organisms that occur mostly in aquatic environments and are either free living or parasitic in plants and animals. Mostly they reproduce by asexual means. Most protozoa have the ability to move by locomotory organelles like pseudopodia, flagella and cilia. Members of protozoa include amoeba, paramecium, leishmania, euglena, and giardia. Plant-like protists such as algae make their own food by photosynthesis. Although these protists may have chloroplasts, they do not have roots, stems, or leaves. And while all plants are multicellular, plant-like protists may be single-celled, colonial, or multicellular. Many single-celled plant-like protists are free-living aquatic organisms. Examples: Chlamydomonas, Euglena etc.

Reading Text Four: Newton's third law of motion

Newton's third law of motion tells us that if body 1 exerts an action on body 2, then body 2 exerts a reaction on body 1 that is equal in magnitude and opposite in direction. We can observe the application of this law on numerous activities in our surroundings. For example, when we want to jump up, we push the ground. The reaction of the ground is what makes us jump up. We move forward because our feet push the road backward. It should be noted that, although the pairs of action and reaction forces have the same value and opposite directions, they do not cancel each other. This is because action and reaction forces are acted on different bodies.

Appendix D: Validity test for the four reading texts sampled from the General Science Textbook of grade 7 for pilot study (n = 40)

Reading text one

Words in the text	Complex count	Not complex count
a		
unicellular	28	12
organism	21	19
is		
an		
that	11	29
consists	22	18
Of		
Single	19	21
Cell		
All		
life		
Processes	23	17
Such	11	29
As		
Reproduction	26	14
Feeding	29	11
Digestion	33	7
Excretion	36	4
Occur	31	9
in		
One		
Amoeba	35	5
Paramecium	38	2
Protozoa	33	7
Examples	13	27
On		
other	9	31
Hand		
Multicellular	29	11
Composed	23	17
Many		
Work	11	29
Coordination	30	10
Plants	9	31
Animals		
Including	24	16
Humans		
Most	17	23
fungi	32	8

Reading text two

Words in the text	Complex count	Not complex count
Plants	9	31
Reproduce	33	7
Without	14	26
seeds	29	11
Are		
Called	11	29
Seedless	32	8
Bryophytes	38	2
And		
Ferns	36	4
Small		
Simple		
Green	9	31
Land		
Dwelling	31	9
Which		
Few	13	27
Aquatic	34	6
Contain	21	19
Three		
Groups	19	21
Liverworts	36	4
Hornworts	37	3
Mosses	29	11
By		
Rather	16	24
Than		
Flowers	14	26
Or		
They		
Have		
Root-like	23	17
Leaf-like	25	15
Structure	19	21
No		
True		
Root	12	28
Stem	28	12
Leaves	22	18
Usually	17	23
Found	15	25
Moist	34	16
Locations	19	21
You		
May	9	31

Find		
Around	18	22
Your		
house		
Even	13	27
The		
Walls	11	29
If		
Area	23	17
Pteridophytes	39	1
Mainly	14	26
Grow	11	29
Well	16	24
Shady	31	9
Places	13	27
Vascular	32	8
Tissues	28	12
To		
Transport	16	24
Food		
phloem	37	3
Water		
Xylem	36	4
Do		
Either	13	27
Instead	10	30
Spores	35	5
Often	12	28
Frond	33	7
Look		
Underneath	29	11
Patches	31	9
Every	8	32
Has		
Under	11	29
It		
Underground	19	21
Rhizome	34	6
From		
develop	6	34

Reading text three

Words in the text	Complex count	Not complex count
Kingdom	26	14
Protista	36	4
diverse	16	24
Group	17	23
Unicellular	28	12
Eukaryotic	37	3
Organisms	23	17
Not		
Plants	9	31
Fungi	32	8
Animals		
Protists	35	5

Nucleus	22	18
Mitochondria	26	14
Organelles	31	9
Chloroplasts	28	12
Can		
Photosynthesize	27	13
Many		
Sexually	24	16
Asexually	28	12
Both		
Occur	31	9
Many		
Environments	16	24
Including	24	16
Water		
Soil	19	21
Inside	13	27
Parasites	30	10
Major	17	23
Groups	19	21
Protozoa	33	7
Microscopic	29	11
Algae	27	13
Single-celled	28	12
Mostly	17	23
Aquatic	31	9
Either	13	27
Free		
Living	9	31
Parasitic	29	11
Means	15	25
Ability	13	27
Move	12	28
Locomotory	34	6
like		
Pseudopodia	39	1
Flagella	39	1
Cilia	37	3
Members	12	28
Amoeba	31	9
Leishmania	38	2
Euglena	39	1
Giardia	37	3
Their		
Own	11	29
Photosynthesis	25	15
Although	19	21
These		
While	17	23
Colonial	32	8
Chlamydomonas	39	1

Reading text four

Words in the text	Complex count	Not complex count
Newton’s	19	21
Third	11	29
Law	10	30
Motion	23	17
Tells	9	31
Us		
Body		
Action	21	19
Exerts	29	11
Reaction	24	16
Equal	11	29
Magnitude	30	10
Opposite	17	23
Direction	18	22
Observe	14	26
Application	22	18
Numerous	26	14
Activities	15	25
Surroundings	23	17
When		
Want		
Jump	18	22
Up		
Push	13	27
Ground	22	18
What		
Makes		
Move	11	29
Forward	25	15
Because		
Feet	27	13
Road	8	32
Backward	23	17
Should	19	21
Be		
Noted	22	18
Although	19	21
Pairs	23	17
Forces	18	22
Same	11	29
Value	16	24
Cancel	19	21
Each	14	26
This		
Acted	22	18
Different	13	27
Bodies	10	30

Summary table for linguistic complexity of the four reading texts

Reading Text	Total Words	Total-not complex	Total-Complex	Complex (%)
Text 1	693	307	1000	69.3%
Text 2	1542	698	2240	68.8%
Text 3	1519	561	2080	73.0%
Text 4	805	675	1480	55.0%

Appendix E: Exploratory Factor Analysis Outputs

Eigen value, pattern matrix, rotated factor matrix, and scree plots for the construct of perceived linguistic competence (PLC)

Total Variance Explained

Factor	Initial Eigenvalues Total	% of Variance	Cumulative %	Extraction Sums of Squared Loadings Total	% of Variance	Cumulative %	Rotation Sums of Squared Loadings Total	% of Variance	Cumulative %
1	9.851	46.909	46.909	9.851	46.909	46.909	5.520	26.286	26.286
2	3.373	16.061	68.210	3.215	15.310	62.219	4.986	23.743	50.029
3	1.990	9.478	77.688	2.490	11.857	74.076	5.050	24.048	74.077
4	.622	2.964	80.651						
5	.423	2.016	82.667						
6	.364	1.734	84.401						
7	.358	1.706	86.107						
8	.316	1.505	87.612						
9	.300	1.430	89.042						
10	.280	1.332	90.374						
11	.266	1.267	91.642						
12	.248	1.182	92.824						
13	.222	1.055	93.879						
14	.216	1.029	94.908						
15	.200	.955	95.863						
16	.196	.936	96.798						
17	.175	.835	97.633						
18	.162	.770	98.403						
19	.124	.589	98.991						
20	.117	.557	99.548						
21	.095	.452	100.000						

Extraction Method: Principal Axis Factoring.

Pattern Matrix[a]

	Component 1	2	3
PPLC1	.030	.852	.047
PPLC2	-.074	.887	.040
PPLC3	-.060	.916	-.002
PPLC4	-.023	.833	.143
PPLC5	.019	.868	.014
PPLC6	.099	.743	-.297
PPLC7	.036	.873	.036
PLLC1	.790	.047	.104
PLLC2	.895	.012	-.056
PLLC3	.903	.000	-.010
PLLC4	.878	.072	-.022
PLLC5	.866	-.032	.086
PLLC6	.889	-.029	-.033
PLLC7	.923	.007	-.065
PLLC8	.836	-.017	.057
PLLC9	.860	-.028	.075
PSLC1	-.010	-.032	.893
PSLC2	.011	-.021	.867
PSLC3	.032	.001	.899
PSLC4	.055	.006	.891
PSLC5	.010	-.008	.914

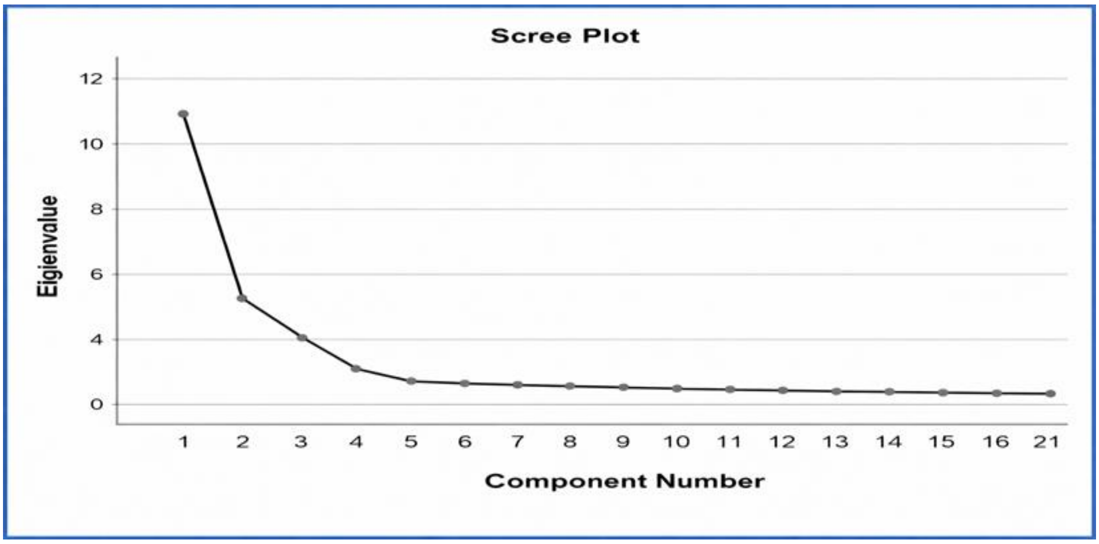
Extraction Method: Principal Factor Analysis.
Rotation Method: Promax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Rotated Factor Matrix[a]

	Factor		
	1	2	3
PLLC1	.898	.182	.237
PLLC2	.849	.182	.196
PLLC3	.847	.163	.206
PLLC4	.836	.244	.232
PLLC5	.834	.165	.294
PLLC6	.832	.185	.200
PLLC7	.831	.150	.213
PLLC8	.830	.169	.278
PLLC9	.829	.229	.215
PPLC1	.129	.891	.139
PPLC2	.219	.845	.193
PPLC3	.198	.823	.169
PPLC4	.125	.823	.168
PPLC5	.216	.820	.195
PPLC6	.193	.811	.266
PPLC7	.135	.581	
PSLC1	.243	.193	.835
PSLC2	.208	.178	.828
PSLC3	.224	.186	.828
PSLC4	.289	.152	.761
PSLC5	.204	.162	.744

Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.
a. Rotation converged in 4 iterations.

Scree plot for the component perceived linguistic competence constructs



Eigen value, pattern matrix, rotated factor matrix, and scree plots for the construct of perceived textbook linguistic complexity (PTLC)

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.345	70.502	70.502	6.029	66.987	66.987
2	.567	6.298	76.800			
3	.434	4.825	81.626			
4	.398	4.419	86.044			
5	.333	3.698	89.742			
6	.287	3.187	92.929			
7	.258	2.865	95.794			
8	.232	2.574	98.368			
9	.147	1.632	100.000			

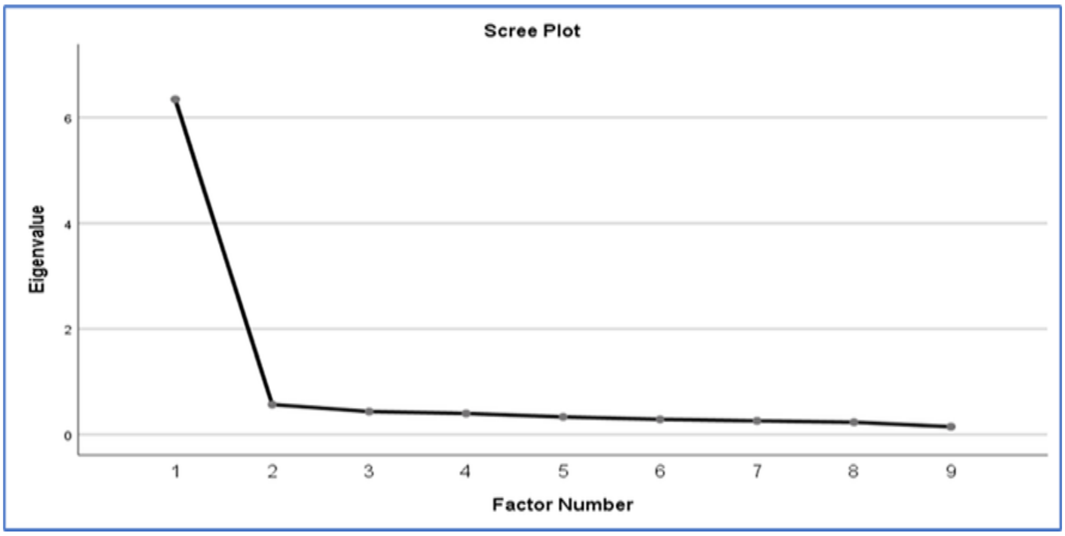
Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
PTLC1	.822
PRLC2	.836
PTLC3	.779
PTLC4	.861
PTLC5	.888
PTLC6	.678
PTLC7	.900
PTLC8	.804
PTLC9	.775

Extraction Method: Principal Axis Factoring.
a. 1 factors extracted. 3 iterations required.

Scree plot for the component perceived textbook linguistic complexity construct



Eigen value, pattern matrix, rotated factor matrix, and scree plots for the construct of engagement profiles (EPs)

Total Variance Explained

Factor	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings[a] Total
1	9.147	27.720	27.720	15.378	46.600	46.600	12.945
2	2.406	7.291	35.011	2.024	6.134	52.734	11.846
3	2.067	6.264	41.275	1.745	5.287	58.021	10.918
4	1.709	5.178	46.453	1.290	3.907	61.928	9.722
5	.797	2.414	68.867				
6	.760	2.302	71.169				
7	.741	2.245	73.414				
8	.639	1.937	75.351				
9	.600	1.820	77.171				
10	.563	1.707	78.878				
11	.551	1.670	80.548				
12	.516	1.564	82.112				
13	.464	1.405	83.517				
14	.437	1.325	84.842				
15	.426	1.291	86.133				
16	.387	1.173	87.306				
17	.371	1.125	88.431				
18	.356	1.078	89.509				
19	.333	1.009	90.518				
20	.324	0.981	91.499				
21	.306	0.926	92.425				
22	.282	0.854	93.279				
23	.274	0.831	94.110				
24	.249	0.753	94.863				
25	.241	0.731	95.594				
26	.237	0.719	96.313				
27	.217	0.656	96.969				
28	.208	0.630	97.599				
29	.195	0.590	98.189				
30	.180	0.544	98.733				
31	.158	0.479	99.212				
32	.140	0.425	99.637				
33	.120	0.363	100.000				

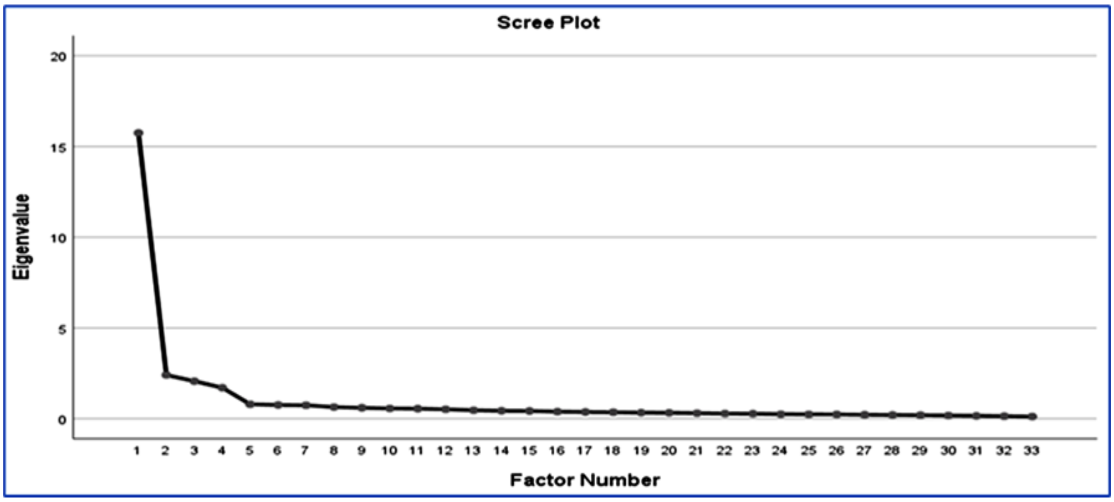
Extraction Method: Principal Axis Factoring.
a. When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

Rotated Factor Matrix[a]

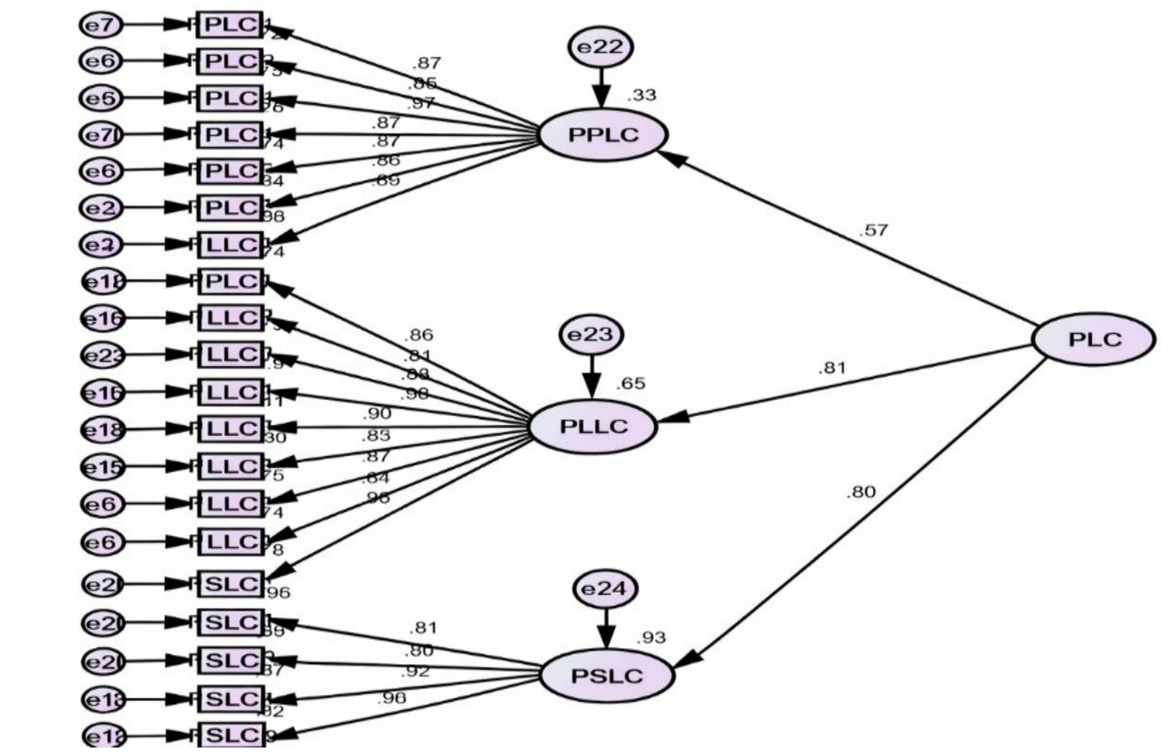
	Factor			
	1	2	3	4
COG1	.585	.228	.308	.113
COG2	.696	.178	.222	.333
COG3	.719	.267	.200	.197
COG4	.637	.330	.301	.178
COG5	.598	.253	.217	.118
COG6	.640	.196	.253	.214
COG7	.712	.267	.236	.277
COG8	.666	.200	.276	.212
COG9	.790	.275	.195	.256
COG10	.780	.240	.229	.185
COG11	.652	.290	.258	.224
BEH1	.238	.602	.216	.192
NEH2	.290	.713	.153	.198
BEH3	.259	.708	.169	.236
BEH4	.231	.672	.321	.149
BEH5	.225	.649	.176	.159
BEH6	.222	.710	.150	.200
BEH7	.201	.685	.212	.289
BEH8	.204	.614	.258	.157
BEH9	.265	.628	.163	.224
EMOT1	.283	.321	.645	.150
EMOT2	.311	.289	.724	.181
EMOT3	.304	.167	.744	.274
EMOT4	.265	.217	.751	.126
EMOT5	.248	.228	.764	.159
EMOT6	.274	.226	.725	.222
EMOT7	.264	.167	.689	.169
AGNT1	.266	.406	.126	.589
AGNT2	.248	.244	.153	.662
AGNT3	.157	.200	.209	.737
AGNT4	.156	.200	.188	.657
AGNT5	.235	.263	.197	.582
AGNT6	.336	.317	.183	.591

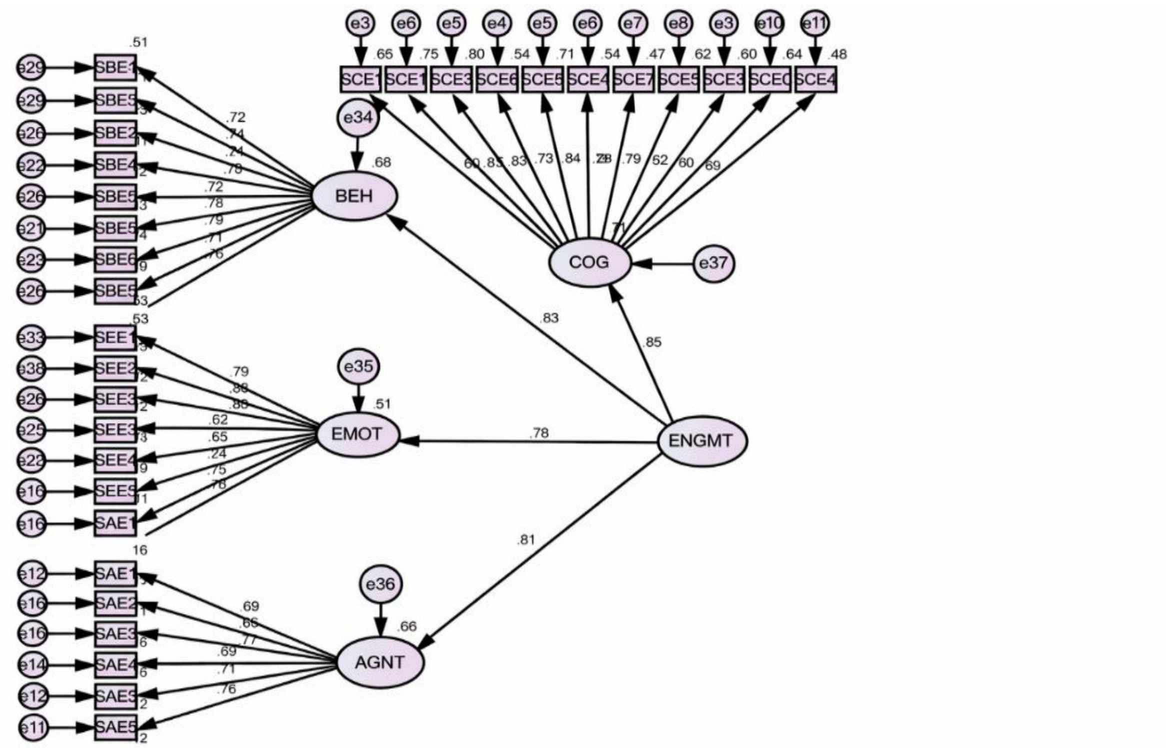
Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Scree plot for the component engagement profiles constructs



***Appendix F:** Second-Order Confirmatory Factor Analysis (CFA) for the Constructs of Perceived Linguistic Competence and Engagement Profiles, respectively*





Appendix G: Syntax for User-defined estimands

```
'PPLC to Scince Achivement via COG
Ind1=PathA*PathU
'PPLC to Scince Achivement via BEH
Ind2=PathB*PathV
'PPLC to Scince Achivement via EMOT
Ind3=PathC*PathW
'PPLC to Scince Achivement via AGENT
Ind4=PathD*PathX
'PLLC to Scince Achivement via COG
Ind5=PathF*PathU
'PLLC to Scince Achivement via BEH
Ind6=PathG*PathV
'PLLC to Scince Achivement via EMOT
Ind7=PathH*PathW
'PLLC to Scince Achivement via AGENT
Ind8=PathI*PathX
'PSLC to Scince Achivement via COG
Ind9=PathK*PathU
'PSLC to Scince Achivement via BEH
Ind10=PathL*PathV
'PSLC to Scince Achivement via EMOT
Ind11=PathM*PathW
'PSLC to Scince Achivement via AGENT
Ind12=PathN*PathX
'PTLC to Scince Achivement via COG
Ind13=PathP*PathU
'PTLC to Scince Achivement via BEH
Ind14=PathQ*PathV
'PTLC to Scince Achivement via EMOT
Ind15=PathR*PathW
'PTLC to Scince Achivement via AGENT
Ind16=PathS*PathX

'Total Indirect Effect of PPLC on Scince Achivement
Tind1=PathA*PathU+PathB*PathV+PathC*PathW+PathD*PathX
'Total Indirect Effect of PLLC on Scince Achivement
Tind2=PathF*PathU+PathG*PathV+PathH*PathW+PathI*PathX
'Total Indirect Effect of PSLC on Scince Achivement
Tind3=PathK*PathU+PathL*PathV+PathM*PathW+PathN*PathX
'Total Indirect Effect of PTLC on Scince Achivement
Tind4=PathP*PathU+PathQ*PathV+PathR*PathW+PathS*PathX

'Total Effect of PPLC on Scince Achivement
Teff1=PathA*PathU+PathB*PathV+PathC*PathW+PathD*PathX+PathE
'Total Effect of PLLC on Scince Achivement
Teff2=PathF*PathU+PathG*PathV+PathH*PathW+PathI*PathX+PathJ
'Total Effect of PSLC on Scince Achivement
Teff3=PathK*PathU+PathL*PathV+PathM*PathW+PathN*PathX+PathO
'Total Effect of PTLC on Scince Achivement
Teff4=PathP*PathU+PathQ*PathV+PathR*PathW+PathS*PathX+PathT
```