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Article abstract

Although technology-enhanced learning has exploded, limited research has examined English language learners' (ELLs) experiences and perceptions of independent online content-based second language learning. To fill this gap, an innovative web application was designed to improve ELLs' grade 10 science content and English language learning. Fifty-six high school ELLs independently completed 30 online modules and then responded to a 12-item questionnaire about the web application, the module content, and their learning. An applied thematic analysis of their responses revealed several benefits and a few challenges that provide insights for the development and improvement of independent online content-based learning for high school ELLs.

High School English Language Learners' Experiences and Perceptions of Independent Online Content-Based Instruction

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Abstract

Although technology-enhanced learning has exploded, limited research has examined English language learners' (ELLs) experiences and perceptions of independent online content-based second language learning. To fill this gap, an innovative web application was designed to improve ELLs' grade 10 science content and English language learning. Fifty-six high school ELLs independently completed 30 online modules and then responded to a 12-item questionnaire about the web application, the module content, and their learning. An applied thematic analysis of their responses revealed several benefits and a few challenges that provide insights for the development and improvement of independent online content-based learning for high school ELLs.

Keywords: content-based language learning, independent online learning, digital literacy, self-regulation

Introduction

Content-based instruction (CBI), which integrates language and content learning objectives, is an effective method of instruction for English language learners (ELLs) (Snow & Brinton, 2023). However, the simultaneous development of language and content knowledge can be a challenging task for both ELLs and their teachers. For teachers, this challenge may be exacerbated by a lack of opportunity for professional development (PD) related to best practices in supporting ELLs in the classroom (Munro et al., 2013; Rizzuto, 2017), which may foster the belief that accommodating language and literacy instruction for ELLs is beyond the purview of teachers who have not specialized in teaching English as an additional language (EAL) (e.g., Rizzuto, 2017). Although PD opportunities can positively impact teachers' attitudes towards ELLs and their preparedness to deliver effective content-based instruction (Song, 2016), teachers may prioritize PD in content area subjects such as science or math over EAL PD (Munro et al., 2013). In schools with limited opportunities for EAL PD and no EAL specialists to support teachers in providing effective CBI for their ELLs, independent online CBI has the potential to supplement content-driven face-to-face instruction and better facilitate ELLs' content and language learning.

With recent advancements in technology that have improved the accessibility and stability of educational and computing technologies, independent online learning has become more common (e.g., Archambault et al., 2022); however, a better understanding of

ELLs' experiences and perceptions of independent online content-based language learning and content delivery systems is needed to inform the design of online CBI applications and to enhance their effectiveness in promoting both content and language learning. Therefore, in the current study, we asked high school ELLs to use an innovative science CBI web application that was created for the purposes of this study, and then we elicited the ELLs' perceptions associated with their experiences.

Literature Review

Content-based language learning is where language teaching is integrated into a content curriculum (Snow, 2014) such as social studies or science. Subject-matter content serves as an organizing framework for instruction as opposed to language structures or tasks. In kindergarten to grade 12 (K-12), content-driven instruction in most subjects emphasizes the development of content knowledge with little attention to language objectives beyond vocabulary learning, whereas CBI makes a dual "commitment to language and content-learning objectives" (Stoller, 2008, p. 59), and teachers develop students' academic content knowledge and linguistic knowledge at the same time. For example, CBI in the subject of science may focus on developing ELLs' content knowledge of scientific phenomena (e.g., photosynthesis) and technical vocabulary, as well as their proficiency in scientific discourse (e.g., developing the skills and strategies to independently read an expository text that describes photosynthesis, writing a lab report on a classroom experiment on photosynthesis). As such, effective CBI requires teachers to have well-developed metalinguistic knowledge of how language forms and functions convey meaning in various subjects (Wong-Fillmore & Snow, 2017). For example, an understanding of how complex noun phrases are used to express new science concepts (e.g., The unusual wobble of the subatomic particle called a muon) can help students develop strategies for creating meaning from clausal elements (e.g., determiner, pre-modifier, head noun, and postmodifier) that form the subject and predicate in a sentence. Form-focused instruction that draws learners' attention to linguistic forms during meaningful communicative activities (Nassaji & Fotos, 2011) is a central component of CBI that promotes content and language learning (Snow & Brinton, 2023).

Reading is a fundamental skill that predicts academic success (e.g., Talmar et al., 2023). Students lacking strong reading skills tend to face difficulties in middle school content-area courses that require a lot of reading such as English language arts, social studies, and science (Zorfass & Urbano, 2008). Therefore, ELLs who are in the process of developing reading skills in English would likely benefit from instruction that fosters their reading comprehension of academic content-area materials. In meta-analyses of second language (L2) reading comprehension (Jeon & Yamashita, 2014, 2022), the two reading skills that correlated most highly with comprehension were L2 grammar knowledge and L2 vocabulary knowledge. These findings suggest that CBI designed to promote the analysis and integration of linguistic forms and patterns at the word, phrase, clause, and sentence levels will foster ELLs' reading comprehension and academic success. Understandably, content area experts, such as secondary high school science teachers, may not have the time (Munro et al., 2013) or metalinguistic knowledge to develop such CBI materials; therefore, the use of premade independent online CBI activities may be a way to address this gap and better facilitate ELLs' content and language learning.

Online Learning

The development of online independent CBI language learning web applications requires an understanding of the features of online learning, independent learning, and independent online learning. According to Silver-Pacuilla and Reder (2008), online learning involves "activities for which web-based content and internet connection and interactivity are integral to the experience for at least a portion of the time" (p. 4); independent learning involves "activities that users engage in… including supplemental activities, activities recommended by instructors or programs" (p. 4); and independent online learning **"**activities involve either self-directed inquiries...or self-study toward an academic or credentialing goal" (p. 4). The academic goal in the current study was to increase the students' chances of success when they enrolled in grade 10 science, as reading and comprehending scientific texts can pose a challenge for ELLs due to the use of complex linguistic forms and functions (e.g., Lee et al., 2013). Although the literature on computer-assisted language learning generally supports the use of various technological resources (e.g., courseware, online resources, text-to-speech tools) to facilitate L2 reading, particularly in the area of L2 vocabulary development (see Liaw & English, 2017 for a review), what is lacking in the research literature is an understanding of how to effectively foster ELLs' understanding of linguistic forms and patterns beyond the word level, that is, at the phrase, clause, and sentence levels using CBI web applications. Although some K-12 educators have the skill to apply technological innovations to foster their students' L2 reading skills in the content areas, many lack the time and the technical support to do so (Liaw & English, 2017) in a way that aligns with best practices in CBI and online learning. In the current study, we addressed these gaps by developing a web application that encompassed a set of independent online learning modules guided by principles of CBI, digital literacy, and online L2 learning.

Digital Literacy

The United Nations Educational, Scientific and Cultural Organization (UNESCO, n.d.) defines digital literacy as involving the confident and critical use of a full range of digital technologies for information, communication and basic problem-solving in all aspects of life. It is underpinned by basic skills in ICT [information and communication technology]: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. (para. 1)

UNESCO's Digital Literacy Framework (Law et al., 2018) consists of seven competence areas:

1. Devices and software operations - knowledge of how to operate devices and software
2. Information and data literacy - knowledge of how to browse, search, and filter data, information and digital content
3. Communication and collaboration - knowledge of how to communicate and interact through digital technologies in different contexts (e.g., educational) which may involve netiquette that guides sharing, engaging in citizenship, and collaborating with others
4. Safety - knowledge of how to protect devices, personal data and privacy

5. Problem-solving - knowledge of how to solve technical problems
6. Digital content creation - knowledge of how to develop and program digital content
7. Career-related competences - knowledge of how to use digital tools and technologies in a particular field

All of these areas have relevance to online learning and were considered in the design of the current study. However, the digital competencies required for independent online language learning involve a multitude of other important literacies that are described in Pegrum et al.'s (2022) Framework of Digital Literacies.

In Pegrum et al.'s (2022) framework, which is specific to language teaching and learning, the authors outline the skills required to access, use, interpret, and design multimodal Internet-mediated contents. They focus on four major literacies, which encompass the ability to communicate, use information, collaborate, and (re-)design or create new meanings through new technologies. The first two, communicating and informing, involve specific literacies that are fundamental to independent online learning. Communicating includes the following specific literacies: traditional print literacy, computer or mobile literacy, hypertext literacy, and visual or multimodal literacy, which involves the knowledge as well as the skill to understand and use hybridities of images, audios, videos, and texts to communicate online. In the context of independent online learning at the high school level, although some print literacy is required for students to interact with the online learning system and the learning content, CBI is intended to foster the development of vocabulary, grammatical, and discourse knowledge alongside reading and writing skills. The second major literacy in the framework, informing, encompasses the following specific literacies: searching for and critically selecting information using technological tools such as search engines, hashtags, and keywords. The third and fourth major literacies in the framework, collaborating and (re-)designing, involve specific literacies for the purposes of managing one's online presence safely, engaging ethically with culturally diverse participants, controlling attention, creating new digital artifacts, and applying a critical lens to digital technology and information. These major literacies are integral to learning in both independent and collaborative online environments, and highlight the centrality and interconnectedness of linguistic, educational, technological, and sociopolitical factors that influence digital learning.

Research conducted in post-secondary contexts has found that independent online learning relies on digital literacy in addition to other factors such as students' perceived satisfaction with online learning. For example, Alqurashi's (2019) study of student satisfaction with online learning environments suggested that the ability to use hardware and software to complete course work, along with ease of access to online course materials predict students' satisfaction with online learning and positive perceptions of learning via online materials.

Online Language Learning

In the field of L2 learning, research conducted with undergraduate students has indicated that students generally have positive perceptions of online language learning (Blake, 2011), as the tasks are often perceived by students to be interesting and enjoyable (e.g., Lee, 2016). Online language learning and the use of digital tools have also been associated with aspects of learners' L2 development, such as the following correlates of

L2 reading comprehension: reading strategies (Tsai & Talley, 2014), vocabulary (Abraham, 2008; Chen & Yen, 2013; Lee & Lee, 2015; Varol & Erçetin, 2021), and grammatical knowledge (Reynolds & Kao, 2021). Tsai and Talley (2014) examined the effects of reading strategy instruction delivered through a learning management system (i.e., Moodle). The authors built a course utilizing the Moodle system to provide EAL learners with independent practice in using reading strategies (2 hours per week over 18 weeks). The system incorporated readings and quizzes with different response formats (true/false, multiple choice, matching) and embedded linguistic tools (dictionaries, translation, websites). Tsai and Talley's findings indicated that the learners' use of the system significantly improved their strategy use and reading comprehension. In addition to quizzes, other interactive digital tools can be embedded in learning management systems that have the potential to scaffold L2 learning. For example, computer-mediated glosses in the form of hypertext links or hover text have been found to facilitate L2 reading comprehension and vocabulary acquisition (Abraham, 2008; Chen & Yen, 2013; Lee & Lee, 2015; Varol & Erçetin, 2021), and drag-and-drop activities that provide immediate explicit error correction can promote grammatical accuracy (Reynolds & Kao, 2021). Findings from these studies have the potential to inform the creation of effective independent online CBI modules for improving ELLs' reading comprehension and content-based learning.

Successful independent online language learning not only requires digital skills, adequate language proficiency, and time to devote to online learning, but it also requires self-regulation (Lee, 2016). Self-regulation refers to "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000, p. 14). Self-regulated learning (SRL) refers to the process of setting learning goals, and then during the learning process, systematically monitoring and controlling cognition, motivation, affect, behaviour, and the learning context in order to meet the goals (Pintrich, 2000). SRL has been recognized as beneficial to online language learning (Zhang & Zou, 2022). Pegrum et al. (2022) specified that monitoring and controlling one's attention (i.e., attentional literacy) is a key component of digital literacy that is needed for combating the digital distractions found in online learning environments. Students who are able to self-regulate their learning tend to be better equipped to sustain their attention on learning tasks amidst distractions (e.g., extraneous visual elements on the computer screen), resulting in improved learning achievement. Positive experiences, such as improved learning, associated with online learning environments have the potential to enhance aspects of university students' SRL, including their motivation to engage in additional online tasks (Zheng et al., 2018). In one study conducted with high school English learners in China, Zheng et al. (2023) explored six self-regulatory factors associated with online language learning: goal setting, time management, task strategies, environment structuring, help-seeking, and self-evaluation, and concluded that online self-regulation predicts students' online engagement and is related to their online participation. Studies of independent online language learning, however, have been predominantly confined to post-secondary contexts. Research needs to be conducted in other settings, such as K-12 in which ELLs are learning English through content-based instruction. Therefore, the purpose of the current study was to investigate independent online content-based

English and science learning designed for high school ELLs through the lens of the students.

Research Question

To develop a better understanding of ELLs' experiences and perceptions of independent online content-based learning and the content-delivery systems used to deliver CBI, we developed a web application with 30 independent online science-based learning modules that high school ELLs completed. The following research question was addressed in this study: what are high school ELLs' perceptions of a web application containing 30 independent online content-based learning modules that was developed to deliver both science and English language/reading instruction?

Method

Participant Recruitment and Characteristics

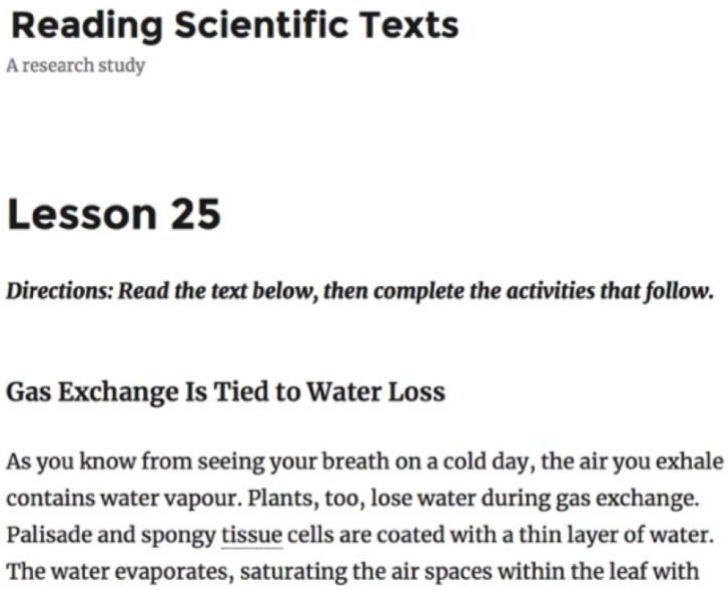
After receiving institutional ethics approval from our university and a local K-12 school board, we contacted the principals of high schools with high ELL populations to request permission to conduct this study in their schools. With the approval of two principals, we sought and received permission from their schools' English as a second language (ESL) teachers ($N = 5$) to (a) recruit ELLs enrolled in their classes and (b) conduct the study during their ESL class time. We explained to the teachers and ELLs that participation was voluntary and could have learning benefits for the ELLs, and we assured the ELLs that their participation would not have any effect on their grades. Finally, we received informed consent from all the teachers and the ELLs. To qualify for inclusion, the ELLs must not have taken Science 10 which is the grade 10 level science course that serves as the prerequisite for higher level high school science courses such as chemistry, physics, and biology. This inclusion criterion was important because the material in the content-based instruction in this study was based on the Science 10 curriculum.

Fifty-six high school ELLs (grades 10–12[1]) participated in this study. They all had recently immigrated to Canada from a variety of countries including China (2%), Colombia (2%), Cuba (2%), Eritrea (2%), Hong Kong (2%), Israel (2%), Kosovo (2%), Mexico (3%), Nepal (2%), Philippines (73%), Portugal (2%), Saudi Arabia (2%), Uganda (2%), and Vietnam (2%). The participants were 51% female and 45% male (4% undisclosed), and their ages ranged from 15 to 18 years ($M = 16.13$). All of them were enrolled in high-school ESL classes, and the amount of ESL instruction they had received in Canada ranged from 1 to 49 months.

[1] In the province where the study was conducted, students can take Science 10 during any year in high school. Because the participants were immigrants and some of them had recently arrived, they may have been placed in grade 11 or 12 based on their age, but they still needed to take Science 10, which is the prerequisite for higher level science courses (i.e., Biology 20 and 30, Chemistry 20 and 30, Physics 20 and 30, [general] Science 20 and 30).

Web Application and Online Content-Based Learning Materials

The development of the web application used in this study was guided by the principles of content-based language learning (Nassaji & Fotos, 2011; Snow, 2014; Snow & Brinton, 2023; Stoller, 2008; Wong-Fillmore & Snow, 2017), digital literacy frameworks (Law et al., 2018; Pegrum et al., 2022), and digital tools and functions that have been reported to benefit online language learning (e.g., Abraham, 2008; Chen & Yen, 2013; Lee & Lee, 2015; Reynolds & Kao, 2021; Varol & Erçetin, 2021) as outlined in the literature. The web application contained 30 independent learning modules that were identical in presentation format, except for the first module which had a 2-minute video that explained the focus of the web application. Each module included a short reading passage (between 400 and 500 words) from a grade 10 science textbook (see Figure 1 for an example). Words in the passages that appeared in the textbook's glossary list were hypertext glossed with their glossary definitions. The web application also presented students with follow-up activities after each reading passage designed to develop students' understanding of scientific discourse (i.e., academic and science vocabulary, grammar, and reading comprehension) (see Figure 2 for examples).



Reading Scientific Texts

A research study

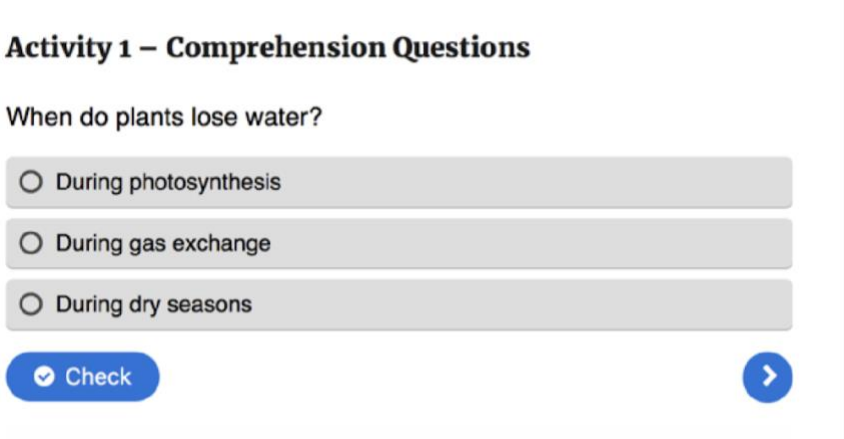
Lesson 25

Directions: Read the text below, then complete the activities that follow.

Gas Exchange Is Tied to Water Loss

As you know from seeing your breath on a cold day, the air you exhale contains water vapour. Plants, too, lose water during gas exchange. Palisade and spongy tissue cells are coated with a thin layer of water. The water evaporates, saturating the air spaces within the leaf with

Figure 1. A Screenshot of a Reading Passage from the Web Application
Note. Reading passage taken from *ScienceFocus 10* by Gue et al. (2004), p. 328.



Activity 2 – Science Vocabulary

Drag the words into the correct boxes

1) a cluster of similar cells that share the same structure and function (e.g., muscle tissue or vascular tissue) _____

2) a small opening in the epidermal layer of a leaf that allows gases in and out _____

3) the evaporation of water from leaves _____

4) cells located on either side of a stoma, that change shape to open or close the opening in order to allow gases in and out _____

5) the process by which plants use light energy to produce food in the form of carbohydrates _____

6) the movement of water molecules across a membrane from an area of higher concentration of water to an area of lower concentration of water _____

7) having the ability to return to its original form after its shape has been distorted _____

8) the boundary around a cell that separates the cell interior from the environment _____

9) the process by which cells obtain energy by breaking down glucose in the presence of oxygen _____

10) water pressure within plant cells that allows them to remain rigid _____

turgor pressure | cell membrane | osmosis | tissue | transpiration | guard cells | photosynthesis | elastic | cellular respiration | stoma

Check

Activity – The Grammar of Science

Match the "regular" English with academic English.

1) Water evaporates = _____

2) Water evaporates from leaves = _____

3) how hard water pushes against a surface = _____

4) where water comes from = _____

5) gas going in and out of something = _____

6) the water is saved by plants for use later = _____

7) a lot of something happening = _____ of something

high rates | water reserves | gas exchange | water source

water pressure | transpiration | evaporation

Check

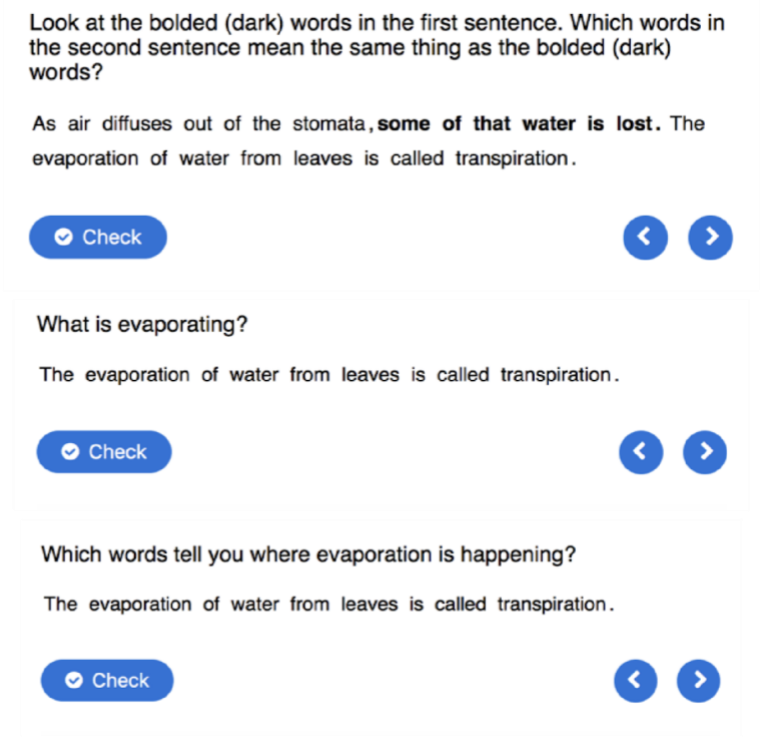


Figure 2. Example Follow-up Activities in the Web Application

With respect to the technical aspects of the web application, it was created with WordPress (https://en-ca.wordpress.org) and several plugins to provide additional functionalities: the Namaste plugin provided learning management system capabilities (i.e., the creation, management, and delivery of the online learning modules); Tooltipy allowed for the addition of hypertext glosses to key vocabulary in the reading passages; and H5P was used to create interactive HTML5 learning activities (e.g., drag and drop, mark the words, multiple-choice, true/false) that provided students with immediate feedback. This suite of technological tools allowed for the accessibility of the web application from any computing device (i.e., desktop computers, laptops, tablets, and smartphones) with any web browser.

Procedures

Over 3 months, students independently completed the modules during their ESL class time. Their ESL teachers provided us with 30-minute blocks of time, three times per week (on average) to conduct the study. The researchers were physically present to monitor the students' engagement with the web application and take field notes. After completing the last of the 30 modules, the students responded to 12 open-ended questionnaire items (see Appendix) about the web application, the modules, and their learning. The questionnaire was designed using simple vocabulary and sentence structure, and the students had access to both the first author and translation tools such as Google Translate while completing the questionnaire.

Data Analysis

We conducted an applied thematic analysis (Guest et al., 2012) of the students' responses to the open-ended questions to identify the ELLs' perceptions of the web application, the modules, and the learning content. Applied thematic analysis "is a rigorous, yet inductive, set of procedures designed to identify and examine themes from textual data in a way that is transparent and credible" (Guest et al., 2012, p. 17) to present participants' experiences in a comprehensive manner. Both authors individually read and reread the participants' responses to the questionnaire items to familiarize themselves with the data and to generate initial codes. Then we met to reach a consensus on the codes; the few disagreements were resolved through discussion. After agreeing on the codes, we met on numerous occasions to reanalyze the entire data set and to define and name the main themes and subthemes that emerged from our analysis. Throughout the analysis process, we kept a reflexive journal in the form of a shared online document to track our decisions and increase the consistency, credibility, and trustworthiness of our results. To enhance the transparency and robustness of our data analysis process, we provide our researcher positioning below.

Researchers' Positioning

As applied linguists and teacher educators, we strive to bridge the gap between research and practice in a variety of educational contexts for ELLs. Our research is aligned with the belief that reality is constructed through individuals' making meaning within their social world and that we, as researchers, are tools for data collection and analysis (Merriam & Tisdell, 2016). Subjective meaning is developed through analyses conducted in multiple contexts (Magolda & Weems, 2002), which has led us to value qualitative research methodologies, such as applied thematic analysis (Guest et al., 2012), and their capacity to explore solutions to practical problems that have the potential to improve teaching and learning.

Results

Our applied thematic analysis revealed a variety of benefits and challenges experienced by high school ELLs in relation to independent online content-based learning (see Table 1). In terms of perceived benefits, the web application and the modules elicited positive student emotions, were easily accessible, contained features that facilitate learning, fostered academic development, and increased motivation to continue independent practice. Although five of the subthemes were interpreted as benefits, the other three subthemes were perceived as challenges related to the students' digital literacy, time, and self-regulated learning. In this section, the themes and subthemes are elaborated with supporting representative quotes.

Table 1
Summary of Main Themes, Subthemes, and Associated Codes

Main theme	**Subtheme(s)**	**Code(s)**

Benefits	Positive emotions	● Interesting ● Enjoyable ● Fun
	Accessible digital learning environment	● Easy to use web app ● Simple interface
	Facilitative learning features	● Repetitive practice ● Interactive learning ● Immediate access to corrective feedback
	Academic development	● Language learning ● Content learning ● Scholastic learning
	Motivation to practice	● Desire for additional independent learning practice in science ● Recommend to others for practice ● Desire for similar independent learning practice in other subjects
Challenges	Digital literacy	● Print literacy ● Devices and software operations
	Time	● Busy schedules ● Other responsibilities
	Self-regulation	● External regulators ● Laziness

Main Theme 1: Benefits

Regarding the first main theme, benefits, the web application and content elicited positive student emotions (subtheme 1). After using the web application to complete the 30 modules, students reported that "it was fun" (Student 9: S9) and "it's very enjoyable" (S41). As evidenced in the following quotes, students also found the content interesting: "The readings is very interesting" (S28); "The information is appealing to read" (S49); "I'm not that good at reading a lot but the website helps me to read more because it's interesting" (S16).

A second benefit was related to the accessibility of the digital learning environment (subtheme 2). Students indicated that the web application was easy to use. For example, they found that "it was straight forward" (S42) and only required the "basic use of a computer" (S31). They thought "it was easy to use" (S47) because "everything was simple and very user friendly. Even my grandma can use it" (S12). Accessibility was also enhanced by the simplicity of the interface: "It was simple and not that flashy to the eye which makes it easy to navigate" (S5); "It's easy because the interface is very simple" (S23).

Facilitative learning features (subtheme 3) included in the web application were also beneficial. Students recognized the value of the opportunity for repetitive practice that was built into the learning modules: “It was good to see the [types of] questions being repeated” (S32); “Doing it again and again will really help you improve...it felt easier to do” (S12); “It’s...repetitive but that helps you remember” (S22). In addition, the interactive elements were appreciated by the students: “The activities were enjoyable because I could learn more and there were things to do for the activities...it helps me better, rather than just reading all day” (S46); “I could learn more and there were things to do for the activities” (S45). In particular, the hypertext glosses and the drag and drop activities were deemed valuable: “It's easy because you'll just drag the words from the choices to answer the questions” (S10); “Some words are new to me, but I can just hover over the words and it'll show the definitions” (S23). The interactive learning activities also provided students with immediate access to corrective feedback which was reported to be helpful: “It’s easy because the answers is also there” (28); “Easier to use and much faster because you can see clearly the answers right away” (S4).

A key benefit from completing the modules was academic development (subtheme 4). The ELLs indicated their completion of the modules fostered their English language learning, in particular their knowledge and comprehension of the lexicogrammatical forms present in scientific discourse as well as their reading fluency: “It helps you to improve your reading ability” (S28); “I learned new words and the grammar of science” (S25); “The website has improved my vocabulary and I read much faster than before” (S22); It helped me read faster through science-y stuffs” (S27). In terms of content learning, students reported outcomes such as “I learned a lot about Science 10” (S21) and “I learn a lot in science like in the potential energy etc.” (S25). In addition to language and content learning, students’ experiences with the web application and modules promoted scholastic learning that transferred across the curriculum: “It is like a review site that will encourage me to read and help answer variety of questions [types]” (S17); “It really helps you to learn words that are not used in conversations but can be useful in academic conversations” (S23); “It’s very helpful to us because we can use what we learned in the other academic subject” (S25).

An additional benefit of the students’ experiences with the modules and web application was a positive impact on their motivation to practice (subtheme 5). They reported they would like to continue engaging with this type of independent online CBI modules, and they recommend it for their peers to use and would like to see similar web applications developed for other subjects: “I can use this if I have a spare time because it will help me improve my reading and learn about science” (S29); “I would use the website for my own practices because it helps me to learn new things...I would also recommend other people to use this website” (S46). They also indicated that they would like to engage in similar activities in other subject areas: “This website should offer other subjects too” (S13).

These findings indicate that overall, the high school ELLs enrolled in this study found that their completion of the modules included in the web application had numerous benefits. However, as described in the next section, the online independent CBI offered through the web application also presented a few challenges that can impact the students’ abilities to fully benefit from this type of independent learning.

Main Theme 2: Challenges

Our analysis of the ELLs' perceptions of the web application and CBI modules revealed three main challenges that may be attributed to the students' lack of digital literacy, time, and self-regulation. Regarding digital literacy (subtheme 6), students reported that their print literacy and their ability to operate digital devices and software sometimes impeded their use of the web application and learning. Vocabulary was a particular issue: "It is difficult for some science vocabulary words that I cannot understand, because I'm not familiar" (S7); "I don't know some of the words" (S35); "It's kind of difficult because there's some word so deep" (S39). A few students also experienced challenges with devices and software operations, as they had difficulty typing in the web application's uniform resource locator (URL: i.e., the web address) or they typed in their passwords incorrectly: "Getting to the website was difficult because keeping the website name is hard" (S21); Sometime I forgot what IP address of the site" (S26); "Confusing for people who are inexperienced with using computer" (S44).

Although all of the students completed the modules during their ESL classes, a few students indicated that finding the time (subtheme 7) to devote to independent online study in the future outside of class could be a challenge due to having other responsibilities and busy schedules: "I got stuff to do" (S3); "I have [other] stuffs to work on" (S19); "Busy at home and busy schedule" (S50).

The last subtheme (subtheme 8) revealed that some students experienced challenges with self-regulation as they expressed a need for external regulators to foster their attention and motivation (e.g., game-like elements, colourful interface, flashy images, or a time challenge): "Add games and group activities…If there are games, it will be more enjoyable" (S1); "Just add extra color so that it will be more interesting to read" (S31); "Use more catchy pictures" (S36); "More flashy images" (S52); "Add the kazoo [Kahoot] timer thing" (S13). Other students admitted that they were lazy so they did not want to read the short passage included in each module: "I'm lazy" (S36); "Students are lazy to learn" (S1); "Too much reading" (S43); "I don't like reading" (S44).

Overall, the high school ELLs reported numerous benefits of independent online CBI and a few challenges that may hinder the effectiveness of the CBI web application developed for this study. These findings are discussed in the following section.

Discussion

Benefits of Independent Online Content-Based Instruction

Through weekly use of the web application over 3 months, students constructed and expanded their knowledge of English as they learned science. In general, the ELLs found that using the web application to supplement their science and English learning was interesting, fun, and enjoyable. Similar positive emotions have been reported by undergraduate students who engaged in independent online language learning (Lee, 2016). In our study, the students' positive emotions were associated with the accessible digital learning environment, the facilitative learning features made possible by digital technology, and the ELLs' perceived academic development.

The independent online CBI learning experience began with ELLs interacting with a web application in the form of a learning management system that many of them found

to be easy to access and use. Ease of access to learning material is an important predictor of positive perceptions of learning via online materials (Alqurashi, 2019). In our study, the ELLs' perceptions of the web application as easy to access and use were also attributable to the basic level of computing skills required and the simplicity of the application's interface. The accessibility of a digital learning environment is tied to the students' abilities to utilize computing hardware and software which are fundamental aspects of digital literacy (Law et al., 2018; Pegrum et al., 2022). In addition to being easy to access, our web application contained various features that facilitated students' positive perceptions and learning. A key facilitative learning feature identified by the ELLs was the repetitive practice they received from reading scientific discourse and engaging with follow-up activities that focused on developing their L2 and content knowledge. In the applied linguistics literature, repetition is purported to increase L2 learning (e.g., Nakata, 2017; Uchihara et al., 2019) and the students in our study indicated that the repetition improved their reading fluency. The web application provided them with individualized interactive learning through science readings that were accompanied by a hover text glossary and H5P-based exercises including drag and drop, click on the correct or incorrect words, multiple-choice, and true/false that provided students with immediate feedback. The computer-mediated hypertext glosses facilitated the students' L2 vocabulary learning and reading comprehension, findings that have been well documented in the L2 literature (Abraham, 2008; Chen & Yen, 2013; Lee & Lee, 2015; Varol & Erçetin, 2021). Similar to the results of Reynolds and Kao (2021), the interactive H5P activities fostered the ELLs' grammatical accuracy. Given that L2 vocabulary and grammar knowledge are two important predictors of L2 reading comprehension (Jeon & Yamashita, 2014, 2022) and practice promotes reading fluency (e.g., Grabe & Yamashita, 2022), these relationships may partially explain the improvements in English reading comprehension and fluency reported by the ELLs in our study.

In addition to L2 learning, the ELLs' indicated that their use of the web application contributed to other aspects of their academic development including their science content learning and scholastic learning. These findings support the value of form-focused instruction in CBI (Snow & Brinton, 2023) and the role of reading as a fundamental skill for academic success (e.g., Talmar et al., 2023) in content area subjects such as science. Our web application provided students with extended practice (i.e., 3 times a week over 3 months) in developing lexicogrammatical strategies to derive meaning from complex noun phrases that helped the ELLs understand science content. Previous research (e.g., Tsai & Talley, 2014) also supports the feasibility of delivering instruction via a learning management system containing interactive activities (true/false, matching, multiple choice) with immediate feedback over an extended period of time to improve strategy use and reading comprehension of expository science texts. In Tsai and Talley's (2014) study, undergraduate ELLs' engagement in repetitive practice with reading strategies improved their comprehension of reading passages taken from the *Test of English as a Foreign Language* (TOEFL). TOEFL passages are excerpts from university undergraduate introductory content area texts (e.g., history, geography, biology).

The ELLs' positive experiences with our web application and modules promoted additional aspects of scholastic learning that they were able to transfer or adapt for use in other classes (e.g., academic language learning and the understanding of how to answer a

variety of question types presented in an online environment). Developing the ability to answer different question formats presented via a learning management system is an important aspect of digital literacy, specifically, knowledge of how to use digital tools and technologies (Law et al., 2018). This ability is particularly important for high school students who are required to write online exams both in school and beyond (e.g., the written portion of a driver's test). Transfer of learning across subject areas and learning contexts has long been an important topic in the field of education including L2 learning and teaching (e.g., James, 2018). Our findings support the argument that transfer is possible and important; however, as Larsen-Freeman (2013, 2020) argued, describing this transfer as transformation may better describe the learning process that occurred in our study—transfer implies that learners simply repeat what they have learned in other contexts, whereas transformation is the optimization of the learners' language resources that results from interacting with different materials and contexts, and iteration and adaptation are key components of this process (Larsen-Freeman, 2013). Although the ELLs in our study described the learning activities as repetitive, the practice they received in reading and parsing numerous variations of complex noun phrases found in 30 different science passages might be more accurately described as iterative and adaptive. This type of practice was different from exact repetition as it provided the ELLs with opportunities to refine and improve their academic knowledge, skills, and strategies. The students reported this practice as beneficial to their learning in other school subjects and contexts.

We also surmise that the students' use of self-regulation strategies played an important role in their learning while completing the online CBI reading tasks. When students monitor their reading comprehension and encounter difficulties, they may enact self-regulation control strategies (Winne & Azevedo, 2022) such as the use of glosses to help them understand the text. Although computer glosses were built into our web application, the students were not required to use them; it was likely that the students' strategic use of the hover text gloss contributed to their L2 and science learning. Research findings reinforce the facilitative role of self-regulated learning strategies and emotions on L2 literacy development (e.g., Abbott & Lee, 2023).

The ELLs' positive emotions and digital learning experiences via the web application supported their academic development and these benefits likely enhanced their motivation to practice, recommend, and learn through the completion of additional independent online content-based activities in science and other subjects. The ELLs' willingness to recommend this form of practice to their peers and their desire for additional independent CBI in science and similar CBI in other subjects are indicative of self-regulation. These findings support prior research on the impact of positive experiences and self-regulation on online learning motivation; for example, Zheng et al. (2018) found that university students' positive online English learning experiences contributed to students' online language learning motivation and self-regulated learning. However, the students in Zheng et al. (2018) were undergraduates who had well-developed digital literacy skills and greater flexibility to structure their online learning than the high school ELLs in our study, where the lack of digital literacy, time for independent learning, and self-regulation emerged as challenges for a few students.

Challenges of Independent Online Content-Based Instruction

Digital literacy skills, limited time outside of class, and self-regulation were three factors that posed some challenges for the ELLs' use of our web application. One fundamental aspect of digital literacy is traditional print literacy (Pegrum et al., 2022), and aspects of print literacy such as vocabulary and reading comprehension were perceived as challenging for some of the ELLs in our study. Another core aspect of digital literacy is the ability to operate devices and software (Law et al., 2018; Pegrum et al., 2022), and a few ELLs experienced technological challenges when logging into the web application. Research (e.g., Lee, 2016) conducted with adult L2 learners has also reported that the reading levels of the online information and the learners' digital competencies may present challenges for the learners. Lee (2016) also found that time was an issue for undergraduate L2 learners; ELLs in our study also reported time as a barrier to independent online learning outside of class. Understandably, high school ELLs may have to prioritize certain time commitments (e.g., caring for younger siblings) over allocating time to independent online learning outside of class. Although time management has been conceptualized as a component of high school English learners' online self-regulation (Zheng et al., 2023), because the ELLs in our study did not elaborate on the nature of their extracurricular activities, we interpreted their references to time as an issue related to the amount of time available rather than their lack of control strategies (i.e., metacognitive planning and monitoring of their time). We did, however, find evidence suggesting that key aspects of self-regulation, controlling their attention and sustaining their learning were an issue for a few students. These students recommended additional supports such as eye-catching colours to help them maintain attention. Issues with online self-regulation were also observed in university L2 students (Lee, 2016).

Implications for Future Research

Some limitations of our study have implications for future research. One limitation is that the students were asked to self-report their perceptions of the CBI web application, the module content, and their learning through a questionnaire in English. Although all of the participants were able to understand and respond to the questionnaire, as evidenced by the representative quotes in the previous section, translating the questionnaire into their first languages and having them report in their first languages may provide additional insights. Other data collection methods and measures (e.g., interviews, observations, science course grades) may also allow for a more in-depth exploration of the themes that emerged in the current study. For example, an interviewer could ask the participants to elaborate on their time commitments, or course grades could be used to triangulate learners' perceived learning gains. Another limitation is that the ELLs were not asked about their previous digital learning experiences. Findings from Zheng et al.'s (2023) study of rural and urban high school English learners in China demonstrated that learners' lack of access to digital learning resources negatively influenced their digital literacy and online self-regulation. Therefore, it may be the case that the ELLs in our study who experienced challenges with digital literacy may have had limited previous access to digital resources before immigrating to Canada. An analysis of the impact of prior digital literacy experience and self-regulation on online independent CBI is a direction for future research. Future research that examines the relationships between digital literacies and the self-regulated learning strategies required for successful independent online content-based language

learning may provide insights to better support high school ELLs.

Preliminary Implications for Effective Independent Online Content-based Language Learning in High School

Although many of the ELLs who participated in the current study possessed fundamental digital literacy skills (see Law et al., 2018; Pegrum et al., 2022) that allowed them to use the web application without assistance, some students could have benefitted from additional digital literacy support. Prior to assigning online content-based learning, to identify students who need additional support, a performance-based assessment of the students' familiarity with and fluency in operating computer/internet technology could be helpful. For example, teachers could provide students with the address of a novel website, a username, and a password, then ask them to navigate to the website and log in. Students who are observed to have difficulties with this task could then be provided with additional instruction and practice in how to access independent online learning resources in order to develop the level of digital fluency needed for independent online content-based learning.

Our findings also imply that the development of both science knowledge and language skills in an independent online learning environment requires a combination of digital literacy skills and self-regulated learning strategies. Because independent online learning requires self-regulation, and digital literacy skills can be improved through the use of self-regulated learning strategies (Anthonysamy et al., 2020; Chen et al., 2021), self-regulated learning strategy instruction would likely help those ELLs who are emergent self-regulators to reduce their reliance on external forms of regulation when completing independent online CBI modules. The addition of goal setting, planning, monitoring and self-reflection checklists and activities to the web application may foster the development of the students' self-regulated learning strategies. Periodic reminders to use task-related, time-management, and help seeking strategies may also scaffold learner self-regulation.

The inclusion of attention grabbing interfaces and additional gamification elements (e.g., reward badges, points, leaderboards, timed competitions) to the web application may also encourage the completion of CBI modules by those learners who need these types of external regulators to increase their motivation, attention, and enjoyment. The gamification of online learning modules may maximize learning for those who do not have a set of well-developed self-regulated learning strategies. In the current study, the ELLs appreciated receiving instant feedback, which is a common element of both gamification (Dehghanzadeh et al., 2021) and computerized dynamic assessment (Poehner & Wang, 2021). The inclusion of other features of computerized dynamic assessment would likely foster students' control and regulation of their learning (e.g., having students elaborate on why their answers are correct or incorrect and, if their justifications are incorrect, providing elaborative feedback on why the answers they selected are incorrect). These additions to the online independent CBI web application in the current study have the potential to further enhance ELLs' understanding of the texts and ultimately lead to transformative independent online content-based language and science learning.

Conclusion

Our study of ELLs' experiences and perceptions of an innovative CBI web application lends support to the effectiveness of online independent CBI for supplementing

both science and L2 language/reading instruction in high school. Through a applied thematic analysis of 56 ELLs' responses to a 12-item open-ended questionnaire, we inferred that the students valued this type of instruction for a number of reasons: They found the web application and modules to be interesting, enjoyable, and fun; the application was easy to use, in part due to the simple interface; the ELLs appreciated the iterative practice in developing lexicogrammatical strategies, and reading strategies for comprehending science texts and building reading fluency; they liked the interactive learning activities and the immediate access to corrective feedback; the ELLs associated their module completion with increases in their L2, content, and scholastic learning. In addition to reporting their positive experiences with using the web application, the ELLs expressed a desire for additional independent online CBI for science and other subjects and that they would recommend this type of learning to their peers. These benefits suggest that the design features and functions we incorporated into our web application can provide ELLs with effective supplementary CBI that classroom teachers may not have the time and resources to develop on their own. Similar web applications designed for other courses may also facilitate ELLs' content and language learning, and ultimately increase their academic success.

Although most of the ELLs who participated in the study embraced independent online content-based learning, a few of them did not. Of those who did not, some experienced issues related to aspects of digital literacy. Others indicated that their busy schedules and out-of-class responsibilities could be potential barriers to their future engagement with independent online learning if not provided the time in class. A few students also recognized that they were lazy or bored because the website was not flashy enough to maintain their attention, suggesting that these ELLs had difficulty self-regulating their learning. Such learners would likely benefit from extra scaffolding or external regulation to support their independent learning. These challenges provide direction for improvements that could be made to independent online CBI in order to enhance ELLs' readiness (i.e., digital literacy skills) and motivation to engage in independent online CBI. In sum, the development of carefully designed independent online CBI that (a) incorporates the beneficial features and functions we included in our web application and (b) addresses the challenges identified by the ELLs in our study, has great potential for assisting content area teachers in enhancing their ELLs' content and language learning.

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Appendix A

Questionnaire

1. How interested were you in using the web application? Please explain.
2. Has completing the modules helped you become better at reading in English? Please explain.
3. How did you feel about the difficulty level of the readings? Please explain.
4. How did you feel about the difficulty level of the activities? Please explain.
5. How difficult was the website to use? Please explain.
6. How enjoyable was your experience using the web application? Please explain.
7. How enjoyable was your experience using the activities? Please explain.
8. Do you have any suggestions for improving the web application? Please explain.
9. Do you have any suggestions for improving the activities? Please explain.
10. Would you continue using the web application on your own? Please explain.
11. Would similar online activities help you improve your reading in other subjects? Please explain.
12. Do you have any other comments you would like to share about your experiences using the web application, the content, or your learning as a result of completing the modules?