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RESEARCH ARTICLE

Technology-Enhanced Strategies for Improving Specialised English Vocabulary Among Industrial Design Students

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ABSTRACT

Specialised English vocabulary is essential for accessing disciplinary knowledge and communicating effectively in professional contexts. However, many English for Specific Purposes learners struggle to remember, understand, and apply specialised terminology due to limited exposure, insufficient contextual practice, and reliance on traditional memorisation. This study investigates the effectiveness of technology-enhanced strategies for improving specialised English vocabulary learning among fourth-year Industrial Design students at Hanoi Open University. An 11-week ESP course was used to implement a mixed-methods intervention for 54 Industrial Design students. The intervention included five technology-augmented strategies. Data were collected through specialised vocabulary pre- and post-tests, two online questionnaires, semi-structured interviews, and classroom observations. Multiple data sources enabled methodological triangulation, providing a more comprehensive evaluation of the intervention outcomes. The results showed that students struggled with vocabulary retention, contextual understanding, and the practical application of technical terminology. The mean score increased from 16.19 on the pre-test to 21.66 on the post-test, for a mean gain of 5.48 points ($p < .001$). The statistical significance of the improvement was confirmed by a paired-samples t-test ($t = 32.68$, $p < .001$, $d = 4.45$: large effect size). The questionnaire, interview, and observation data also showed that students' perceptions of the use of digital learning tools were positive, especially in vocabulary organization, repeated practice, contextual learning, and independent learning. The results also imply that the application of technology-enhanced strategies grounded in evidence-based principles of vocabulary acquisition can effectively promote specialised English vocabulary development in ESP contexts.

Keywords: digital learning tools, English for Specific Purposes, Industrial Design students, specialised English vocabulary learning, technology-enhanced strategies, vocabulary learning strategies.

1. INTRODUCTION

1.1. The Importance of ESP and Specialised Vocabulary for Industrial Design Students

English has become crucial for accessing academic knowledge and for professional communication, particularly in specific fields. English for Specific Purposes (ESP) is designed to meet the varied linguistic requirements across disciplines (Dudley-Evans & St John, 1998). Unlike General English, ESP emphasises language for authentic tasks in professional contexts. For university students, particularly in Industrial Design, competence in specialised English is vital for engaging in disciplinary discourse, accessing resources, and communicating design concepts effectively. Recent ESP research emphasises that effective disciplinary language learning requires students to develop linguistic knowledge together with the ability to engage in the specialised discourse practices of their academic and professional communities (Hyland & Jiang, 2021). Tasks such as reading design briefs, interpreting technical documents, and presenting ideas require a solid grasp of specialised vocabulary. Vocabulary knowledge is essential in ESP, as specialised terms convey meanings linked to disciplinary concepts. Understanding a word requires awareness of its form, meaning, and usage in context, as outlined by Nation (2013). For instance, Industrial Design students must grasp the term 'ergonomic' not only in isolation but also in phrases such as 'ergonomic design' and 'ergonomic considerations'. A lack of specialised vocabulary can hinder students' ability to access knowledge and

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communicate effectively in their field. While they may grasp general ideas, they struggle to discuss technical content or describe products. Therefore, developing specialised vocabulary is critical in ESP courses tailored for Industrial Design students. Additionally, recent studies further validate the significance of vocabulary knowledge as a fundamental component of successful academic and professional communication since learners' inability to understand discipline-specific texts and to articulate complex ideas accurately can be attributed to lack of lexical knowledge (Coxhead et al., 2017).

1.2. Challenges in Learning Specialised English Vocabulary

Specialised vocabulary is important, but discipline-specific terminology can be difficult for many ESP learners to acquire. In contrast, specialised vocabulary is used less often in everyday language than general English, and it usually takes repeated exposure to be remembered and used effectively. According to Schmitt (2008), vocabulary building is a slow process that requires repeated exposure to words in various contexts. One of the major problems in vocabulary learning is retention. Learners might immediately recognise new words after instruction but forget them when they do not encounter or use them regularly. This difficulty can be explained by the depth of processing hypothesis, which holds that vocabulary learning is more effective when learners engage in meaningful cognitive activities rather than simply memorizing word forms and meanings (Laufer & Hulstijn, 2001). Therefore, vocabulary learning requires special tasks that encourage learners to analyse, retrieve, and use new vocabulary in meaningful contexts. Research on vocabulary learning shows that long-term retention requires active retrieval and practice, not mere exposure or memorization (Roediger & Butler, 2011). This is particularly true of ESP learners, who often encounter technical vocabulary only in restricted academic settings. Another challenge is understanding context. Some specialised words have meanings that depend on the disciplinary context. A word that in ordinary English means one thing in design, engineering, or scientific communication can mean something more specific. Thus, vocabulary learning from word lists may not be enough to understand how these terms are used professionally. Pronunciation and productive use also pose problems. When reading, students may know what technical words mean but not how to pronounce them or use them in speaking or writing. The distinction parallels the difference between receptive and productive vocabulary knowledge. Learners may recognise specialised vocabulary when they encounter it in reading materials but be unable to use it actively in oral or written communication (Hulstijn, 2001). For ESP learners, developing productive knowledge is especially important, as professional communication requires the accurate use of discipline-specific terminology. This limitation can affect industrial design students when presenting design concepts, explaining product functions, and communicating with international professionals. These challenges indicate that effective ESP vocabulary teaching should go beyond translation-based learning. They should provide students with opportunities for contextualised learning, repeated retrieval, and meaningful use of language.

1.3. Effective Strategies for Specialised Vocabulary Learning

Research on second-language vocabulary learning shows that appropriate vocabulary learning strategies are key to effective vocabulary development. Gu and Johnson (1996) classified vocabulary learning strategies into four categories: metacognitive, cognitive, memory, and activation strategies. These strategies include planning vocabulary learning, analyzing word structures, using memory associations, consulting dictionaries, and actively using new vocabulary. Of these, contextual learning is particularly important in ESP environments because specialised vocabulary is closely tied to disciplinary knowledge. When students learn a term in authentic contexts, they learn not only what a word means but also when and how to use it. Students of industrial design can improve vocabulary learning by associating terminology with product images, design cases, technical descriptions, and professional communication tasks. Memory and retrieval strategies are also very important for vocabulary development. Nation (2013) states that vocabulary knowledge develops through repeated encounters and opportunities for meaningful use. Retrieval practice facilitates long-term retention by encouraging learners to actively retrieve information rather than passively review it (Roediger & Butler, 2011). Spaced repetition also enables learners to review vocabulary systematically over time, reducing forgetting and strengthening lexical knowledge. Spaced repetition also allows learners to review vocabulary systematically over time, reducing forgetting and strengthening lexical knowledge. Technology-supported learning environments can further extend opportunities for vocabulary practice by allowing learners to access learning materials, review vocabulary independently, and engage in language activities outside of classroom time (Burston, 2015). Thus, effective specialised vocabulary instruction should be a multi-strategy approach that includes vocabulary classification, contextual learning, memory techniques, retrieval practice, and productive language activities. However, these strategies are only effective when implemented in learning environments that offer sufficient opportunities for repeated exposure and independent practice.

1.4. Technology-Supported Strategies for Vocabulary Learning

Recent advances in educational technology have opened new possibilities for improving vocabulary learning by providing learners with flexible access to learning materials, multimodal input, immediate feedback, and opportunities for autonomous practice. Technology-supported language learning presents vocabulary through combinations of text, images, audio, video, and interactive activities, which may support deeper lexical processing. Digital vocabulary applications, such as Quizlet, offer learners flashcards, pronunciation models, images, definitions, and self-testing activities. These features support repeated retrieval and spaced practice, principles deemed important for long-term vocabulary retention. Moreover, mobile-assisted language learning environments can extend vocabulary practice beyond classroom boundaries by allowing learners to access digital resources flexibly and engage in self-directed practice according to their individual learning needs (Stockwell, 2022). Studies have shown that digital flashcard applications can improve vocabulary learning outcomes when integrated with appropriate pedagogical strategies (Nguyen & Le, 2022). Online dictionaries and digital language resources make it easier for learners to develop vocabulary by allowing them to explore pronunciation, word families, collocations, and authentic examples. These functions are especially useful in ESP contexts, since specialised vocabulary requires more than simple definitions. Students must learn how the terms are used in professional discourse. Gamified technologies like Kahoot can also increase learner engagement through interactive vocabulary practice and instant feedback. Multimedia resources, including online videos, product images, and digital design materials, can further support Industrial Design students by connecting linguistic forms with visual and professional concepts. Nevertheless, technology does not automatically guarantee good vocabulary learning. Research in computer-assisted language learning emphasises that the effectiveness of digital tools depends on how they are integrated into pedagogically meaningful activities that promote interaction, learner engagement, and language development (Chapelle, 2001). It is the way digital tools are integrated with sound pedagogical principles that determines the effectiveness of technology-supported learning. Bueno-Alastuey and Nemeth (2020) suggest that technology-based activities might be most beneficial when they increase meaningful exposure, facilitate active participation, and enhance learner involvement. Technology should therefore act as a support mechanism for effective vocabulary learning strategies, rather than simply replacing traditional instruction.

The principles of multimedia learning can also explain the effectiveness of technology-enhanced vocabulary learning. Mayer (2021) suggests that learners comprehend and recall information more effectively when verbal and visual representations are well integrated. Multimedia resources (e.g., images, audio recordings, videos, contextual examples) can help learners establish meaningful links between linguistic forms and conceptual knowledge in language-learning settings. This principle is especially relevant to Industrial Design students, as vocabulary is often specialised to visual ideas, product features, materials, and design processes. Thus, combining textual explanations with visual representations might lead to a better understanding of technical terms.

Moreover, technology-supported learning environments might facilitate learners' autonomy by enabling them to determine the pace, frequency, and methods of vocabulary practice. Benson (2013) describes learner autonomy as the capacity to manage and direct one's own learning. Digital tools, such as vocabulary apps, online dictionaries, and learning platforms, offer students opportunities to review materials independently, track their progress, and select resources that suit their individual needs. For ESP learners who may need to continue developing vocabulary beyond classroom instruction, fostering autonomous learning behaviours is an important component of effective vocabulary acquisition.

1.5. Research Gap and Significance of the Study

Despite prior research on vocabulary learning strategies and technology-assisted language learning, significant gaps remain. Most studies have focused on general English learners and specific academic fields, neglecting Industrial Design students, who need vocabulary relevant to visual communication and design processes. Additionally, research has primarily examined either vocabulary strategies or attitudes toward technology, with few studies integrating both through contextual learning, multimedia resources, and digital assessments in ESP courses. There is also a lack of evidence from Vietnamese educational settings on technology-supported vocabulary learning tailored to particular disciplines. Therefore, an effective technology-enhanced ESP vocabulary intervention should not only provide digital resources but also integrate multimedia learning principles, retrieval practice, contextualised activities, and opportunities for learner autonomy. This study aims to fill these gaps by exploring technology-enhanced vocabulary learning strategies for fourth-year Industrial Design students at Hanoi Open University, contributing empirical evidence on integrating technology with vocabulary strategies for specialised language development in ESP contexts.

1.6. Research Objectives

This study aims to: identify the challenges fourth-year Industrial Design students face in learning specialised English vocabulary; examine students' perceptions of technology-enhanced strategies for learning specialised English vocabulary; and evaluate the effectiveness of these strategies in improving students' performance in specialised English vocabulary.

Research Questions

RQ1. What challenges do fourth-year Industrial Design students encounter in learning specialised English vocabulary?

RQ2. What are students' perceptions of technology-enhanced strategies for learning specialised English vocabulary?

RQ3. To what extent do technology-enhanced strategies improve students' specialised English vocabulary performance?

2. METHODOLOGY

2.1. Research Design

The study used a mixed-methods embedded intervention design to examine the effectiveness of technology-supported strategies in improving industrial design students' specialised English vocabulary learning. A mixed-methods approach was chosen because vocabulary development involves measurable learning outcomes as well as learners' experiences, perceptions, and learning behaviours. The quantitative part focused on measuring changes in students' specialised English vocabulary performance using a pre-test and post-test design. Questionnaires were also used to collect students' perceptions of the difficulties in vocabulary learning and the strategies supported by technology. The qualitative part of the study used semi-structured interviews and classroom observations to gain a richer insight into students' experiences of the intervention and to help explain the quantitative results. This combination enabled the study to investigate not only improvements in students' performance in specialised vocabulary but also the contribution of technology-supported strategies to their learning process.

2.2. Pedagogical Setting and Participants

The study was conducted at the Faculty of Industrial Design, Hanoi Open University, as part of an ESP course for fourth-year Industrial Design students. The course was designed to deepen students' English knowledge specific to their field of study and future professional contexts. The course materials were adapted from Career Paths: Art & Design (Evans et al., 2013), which provides specialised English content for design fields. The course focused on vocabulary and expressions students can use when discussing materials, product features, the design process, production techniques, and professional communication. A purposive sampling method was used because the participants were representative of the specific learner group targeted by the research objectives. The participants were 54 fourth-year Industrial Design students at Hanoi Open University. These students were selected because a considerable part of their seventh-semester ESP course was devoted to acquiring specialised vocabulary, with the expectation that they would use design terminology in English in academic and professional environments. Students participated in the following during the 11-week intervention period: 45 classroom sessions with teacher-led vocabulary instruction and collaborative activities; 90 self-study sessions in which students completed technology-supported vocabulary learning activities outside class; and three students also volunteered for semi-structured interviews, providing detailed reflections on their learning experiences.

2.3. Technology-Supported Vocabulary Learning Intervention

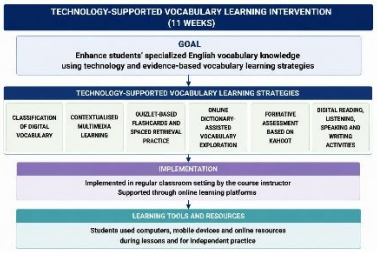

Figure 1. Technology-supported vocabulary learning intervention

As shown in Figure 1, the intervention was implemented for 11 weeks as an integral part of the ESP course. The intervention aimed to enhance students' specialised English vocabulary knowledge by using technology and evidence-based vocabulary learning strategies. Rather than utilizing technology as a stand-alone activity, digital

tools were integrated throughout the intervention to support various stages of vocabulary development, including identification, contextual understanding, memory formation, retrieval practice, pronunciation development, and productive language use. The technology-supported strategies included classification of digital vocabulary; contextualised multimedia learning; Quizlet-based flashcards and spaced retrieval practice; online dictionary-assisted vocabulary exploration; formative assessment using Kahoot; and digital reading, listening, speaking, and writing activities. The intervention was implemented in the regular classroom setting by the course instructor and supported through online learning platforms. Students used computers, mobile devices, and online resources during lessons and for independent practice.

2.4. Weekly Intervention Procedures

Table 1. The structure of the 11-week technology-supported vocabulary intervention.

Week	Instructional focus	Technology-supported activities	Learning objectives
Week 1	Orientation, survey, and pre-test	Students completed the initial questionnaire and vocabulary pre-test through online forms. The teacher introduced digital learning platforms and explained technology-supported vocabulary learning procedures.	Identify students' initial vocabulary knowledge, difficulties, and learning needs.
Week 2	Identifying and classifying specialised vocabulary	Students analysed digital design texts, product descriptions, and online materials. They classified vocabulary by topic, word form, meaning, and design categories using digital vocabulary tables.	Develop awareness and systematic organization of specialised terminology.
Weeks 3–4	Linking vocabulary to real contexts	Students learned vocabulary through multimedia resources, including product images, design videos, online articles, and authentic design materials. They matched terms to visual examples and used vocabulary in context.	Improve contextual understanding and reduce isolated memorization.
Weeks 5–6	Memory techniques and retrieval practice	Students created and practiced Quizlet vocabulary sets that included words, images, pronunciations, definitions, and example sentences. Spaced review and self-testing activities were assigned regularly.	Strengthen vocabulary retention and long-term memory.
Weeks 7–8	Technology-supported vocabulary development	Students used Quizlet, online dictionaries, Kahoot quizzes, and online learning software to review vocabulary, check pronunciation, explore collocations, and receive immediate feedback.	Increased engagement, learner autonomy, and accuracy of vocabulary use.
Weeks 9–10	Integrating vocabulary with four language skills	Students applied vocabulary through technology-supported listening, speaking, reading, and writing activities. Tasks included watching design-related videos, reading digital texts, recording presentations, and writing product descriptions.	Transfer vocabulary knowledge from recognition to practical communication.
Week 11	Revision, post-test, and second survey	Students completed digital review activities, a post-test, and a questionnaire. Selected students participated in interviews.	Evaluate vocabulary improvement and students' perceptions of the intervention.

2.5. Data Collection Instruments and Procedures

Three instruments were used to collect quantitative and qualitative data as shown in Figure 2.

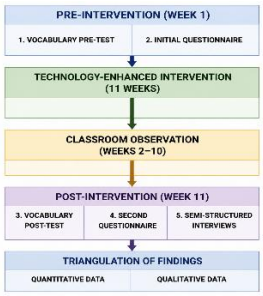

Figure 2. Data Collection Instruments and Procedures

2.5.1. *Vocabulary Tests*

Students' vocabulary performance after the use of technology-supported strategies was measured using a specialised English vocabulary test administered before and after the intervention. To make the students' performance before and after the intervention comparable, both the pre-test and post-test were administered using the same format. The test consisted of 45 items, including multiple-choice, constructed-response, and short-answer questions. The test aimed to evaluate different aspects of specialised vocabulary knowledge, such as the ability to recognise discipline-specific terminology, understand word meanings, identify appropriate vocabulary use, and apply specialised terms in contextualised situations related to industrial design.

A pre-test was administered at the beginning of the intervention to assess students' vocabulary knowledge. A post-test was administered at the end of the 11-week intervention to evaluate students' vocabulary improvement following technology-enhanced learning activities. Pre- and post-test scores were compared to determine the intervention's effectiveness in improving students' performance in specialised English vocabulary.

2.5.2. *Questionnaires*

Quantitative data on students' perceptions, learning difficulties, and evaluations of technology-supported vocabulary learning strategies were collected through two online questionnaires distributed via Google Forms. Online questionnaires were an efficient and convenient method for data collection and for students to complete during the intervention.

The initial questionnaire was distributed before the intervention and examined students' perceptions of the importance of specialised English vocabulary, the problems encountered in vocabulary learning, and their prior vocabulary learning practices. This questionnaire aimed to identify students' initial needs and problems in learning specialised vocabulary.

The second questionnaire was administered after the intervention to explore students' perceptions of technology-enhanced vocabulary learning strategies. The study examined students' assessments of the effectiveness of the implemented activities: digital vocabulary classification, contextual learning, Quizlet-based practice, online dictionary use, gamified activities, and technology-supported four-skill practice. The questionnaire also asked about the methods students prefer for learning vocabulary and the advantages they perceive in using technology for vocabulary learning in ESP.

Prior to data collection, all questionnaire items were reviewed by three language specialists to assess the validity and appropriateness of the questionnaire instruments. A pilot test with five students was also conducted to assess the clarity, relevance and suitability of the questionnaire items. The questionnaires were revised based on feedback from the experts and pilot participants.

2.5.3. *Interviews and Classroom Observations*

Semi-structured interview data were analysed using thematic analysis to explore students' experiences and perceptions of the technology-enhanced vocabulary-learning intervention. The analysis followed four main steps. First, the interview recordings were transcribed and reviewed repeatedly to ensure familiarity with the data. Second, meaningful statements related to students' vocabulary learning experiences, technology use, and perceived learning outcomes were identified and coded. Third, similar codes were grouped into broader categories. Finally, the categories were reviewed and refined to identify the main themes that represent students' experiences with the intervention.

The thematic analysis yielded four major themes: (1) improved vocabulary organization and reduced learning difficulties through digital classification, (2) enhanced vocabulary retention through repeated, technology-supported exposure, (3) improved contextual understanding through multimedia and authentic materials, and (4) increased confidence and ability to apply specialised vocabulary in academic and design-related tasks.

These themes provided qualitative explanations for the quantitative findings, particularly the significant improvement in post-test vocabulary performance and students' positive perceptions of technology-enhanced strategies.

Classroom observations were conducted to monitor student engagement and behaviours during technology-supported activities, supplementing data from questionnaires and interviews to validate the intervention's implementation and effectiveness. The data collection procedures were organised according to the intervention timeline as follows:

Table 2. Data collection timeline

Stage	Time	Data collection activities
Before intervention	Week 1	First questionnaire and specialised vocabulary pre-test
During intervention	Weeks 2–10	Classroom observations and monitoring of technology-supported learning activities
After intervention	Week 11	Specialised vocabulary post-test, second questionnaire, and semi-structured interviews

2.6. Data Analysis

The effectiveness of a technology-enhanced vocabulary learning intervention was assessed by analysing both quantitative and qualitative data to gain insights into students' learning experiences. Quantitative data collected through vocabulary tests and questionnaires were analysed using SPSS Statistics. Descriptive statistics, including frequencies, means (M), and standard deviations (SD), were used to summarise students' performance and perceptions of technology-supported vocabulary learning. The mean scores from the questionnaire, interpreted on a five-point Likert scale, indicated students' level of agreement with the learning strategies.

To assess the effect of the intervention after an 11-week treatment, a paired-samples t-test was used to compare students' performance on pre- and post-tests of vocabulary, with significance set at $p < .05$. This allowed evaluation of significant improvements in knowledge of specialised vocabulary achieved through the technology-enhanced activities.

Interviews and classroom observations were analysed using thematic analysis, guided by an inductive approach. This process involved becoming familiar with the data, coding meaningful statements about vocabulary learning experiences and technology use and grouping them into broader themes. Themes explored students' challenges in vocabulary learning, perceived benefits of technology strategies, vocabulary retention, learner autonomy, engagement, and classroom interaction.

The observation data were analysed using thematic analysis. The researcher examined the observation notes from the full intervention and identified patterns in students' engagement, use of technology, behaviours related to practicing vocabulary, peer interaction, and use of specialised terminology. These themes were then compared with the findings from the questionnaires and interviews to ensure consistency across data sources. The combination of observational evidence enabled the researcher to explore students' reported perceptions alongside their actual behaviours in technology-enhanced vocabulary learning activities.

During the interpretation phase, integrating quantitative and qualitative findings provided a more complete understanding of the intervention's outcomes. Statistical data indicated trends in improvement and student perceptions, while qualitative insights explained how technology strategies facilitated vocabulary learning. This integration strengthened the findings' validity by linking measurable outcomes to students' experiences and observed behaviours.

Data reliability/validity: To enhance the credibility of the findings, methodological triangulation was used to collect data from multiple sources, including vocabulary tests, questionnaires, interviews, and classroom observations. Using both quantitative and qualitative data enabled cross-validation of findings and reduced reliance on a single data source.

To strengthen the confidence and validity of the findings, the researcher employed data triangulation by combining several sources of evidence, including pre- and post-tests on specialised vocabulary, student questionnaires, semi-structured interviews, and classroom observations. Each data source provided a distinct perspective on the effectiveness of the technology-enhanced vocabulary learning intervention. Vocabulary tests provided quantitative evidence of changes in students' performance on specialised vocabulary, and questionnaires explored students' perceptions of technology-supported strategies. Interview data offered deeper insights into students' learning experiences and perceived benefits of the intervention. At the same time, classroom observations provided behavioural evidence of students' engagement and the actual use of technology-enhanced learning strategies during classroom activities. By comparing and integrating findings across these sources, the

study reduced reliance on a single measurement method. It provided a more comprehensive understanding of how technology-enhanced approaches impacted students' specialised vocabulary learning.

3. RESULTS

3.1. Students' Challenges in Learning Specialised English Vocabulary

The first research question examined the challenges fourth-year industrial design students faced in acquiring specialised English vocabulary. The results of the first questionnaire (N = 54) showed that students struggled mainly with vocabulary retention, the large volume of specialised terms, contextual understanding, and distinguishing similar vocabulary items.

As shown in Table 1, the most common difficulty was forgetting specialised words if not reviewed regularly, reported by 30 students (55.6%). Too many new words to remember was the second most common challenge, reported by 23 students (42.6%). Furthermore, 21 students (38.9%) reported difficulty guessing the meaning of words without pictures or translations, and 20 students (37.0%) said that many specialised words looked similar and were easy to confuse.

Table 3. Challenges faced by students in learning specialised English vocabulary

Rank	Challenge	Frequency (n)	Percentage (%)
1	Specialised words are easy to forget if not reviewed often	30	55.6
2	Too many new words, difficult to remember all	23	42.6
3	Difficult to guess meanings without pictures or translation	21	38.9
4	Many words look similar and are easy to confuse	20	37.0

Table 3 shows that the students' problems were not only in recognising word meanings but also in retaining vocabulary and understanding context. These results underscore the importance of learning strategies that involve repetition, meaningful contexts, and active engagement with vocabulary.

3.2. Students' Perceptions of Technology-Enhanced Vocabulary Learning Strategies

The second research question examined students' perceptions of technology-enhanced strategies for improving specialised English vocabulary learning. Data from the second questionnaire (N = 54) indicated generally positive attitudes toward integrating technology into vocabulary learning. Students rated various strategies on a five-point Likert scale, with 1 indicating Strongly Disagree and 5 indicating Strongly Agree. The findings showed that the mean scores for all technology-supported strategies were above 3.70, indicating positive perceptions.

Table 4. Students' perceptions of technology-enhanced vocabulary learning strategies

Technology-enhanced vocabulary learning strategy	Mean (M)	Standard Deviation (SD)	Interpretation
Creating digital vocabulary lists organised by topics helps remember specialised vocabulary more effectively	4.11	0.79	Positive
Using digital tools to identify and classify specialised vocabulary is useful	4.02	0.92	Positive
Using digital platforms for repeated review and retrieval practice supports long-term vocabulary retention	3.94	0.81	Positive
Reading and listening to authentic digital design materials helps expand specialised vocabulary knowledge	3.89	0.82	Positive
Learning specialised vocabulary through digital examples and real-life design contexts improves understanding	3.89	0.79	Positive
Reviewing specialised terms through authentic digital texts, lectures, and multimedia materials is effective	3.89	0.86	Positive
Practicing new specialised terms through technology-supported speaking and writing activities improves retention	3.91	0.71	Positive
Creating digital mind maps helps organise and memorise specialised vocabulary	3.70	0.90	Positive

The second research question focused on students' perceptions of technology-enhanced strategies for learning specialised English vocabulary. In the post-intervention questionnaire, students rated these strategies positively, with mean scores above 3.50 on a five-point Likert scale. The first strategy was creating digital vocabulary lists organised by topic (M = 4.11, SD = 0.79). This underscores the importance of systematic vocabulary organization to improve memory and efficiency. Attitudes toward using digital tools for vocabulary classification were also rated highly (M = 4.02, SD = 0.92), indicating a positive orientation toward technology-supported classification.

As shown in Table 4, students also displayed a positive attitude toward technology-supported retrieval and contextual learning activities. Repeated review via digital platforms was rated highly (M = 3.94, SD = 0.81), indicating the role of repeated exposure in vocabulary retention. Students also evaluated productive vocabulary use in speaking and writing practices positively (M = 3.91, SD = 0.71). Students appreciated the use of authentic digital materials, and reading and listening to design-related content (M = 3.89, SD = 0.82) helped them increase their vocabulary. At the same time, real-life examples contributed to their understanding (M = 3.89, SD = 0.79). Digital mind maps were the lowest-ranked activity (M = 3.70, SD = 0.90) but still indicated a positive perception. Overall, the results indicated that students perceived the use of technology-enhanced vocabulary learning strategies as effective for organizing, reviewing, understanding, and applying specialised English vocabulary, especially when consistent with established vocabulary learning principles such as contextualization, retrieval practice, and active use.

3.3. Effectiveness of Technology-Enhanced Strategies on Students' Specialised Vocabulary Performance

The third research question examined the effect of using technology-enhanced vocabulary learning strategies on students' achievement in specialised English vocabulary. A paired-samples t-test was conducted to assess students' vocabulary test scores before and after the 11-week intervention.

Students showed significant improvement after participating in the technology-enhanced vocabulary learning activities, as shown in Table 3. The average pre-test score was 16.19 (SD = 2.74), increasing to 21.66 (SD = 2.44) on the post-test, for an average gain of 5.48 points.

Table 5. Comparison of Students' Pre-Test and Post-Test Vocabulary Scores

Assessment	N	Mean (M)	Standard Deviation (SD)
Pre-test	54	16.19	2.74
Post-test	54	21.66	2.44

In Table 5, the difference between the students' pre-test and post-test scores was statistically significant using a paired-samples t-test, $t(53) = 32.68$, $p < .001$. Effect size analysis also indicated a very large effect (Cohen's $d = 4.45$), suggesting that the improvement was not only statistically significant but also educationally meaningful.

Table 6. Paired-Samples T-Test Results for Vocabulary Performance

Comparison	Mean Difference	t	df	p	Cohen's d
Post-test – pre-test	5.48	32.68	53	< .001	4.45

As shown in Table 6, the students' post-test score was significantly higher than their pre-test score, as reported in Table 4. The mean difference between the two assessments was 5.48 points, and the paired-samples t-test showed that this improvement was statistically significant, $t(53) = 32.68$, $p < .001$. The effect size was very large (Cohen's $d = 4.45$), making the improvement not only statistically significant but also educationally significant.

The dramatic improvement in students' vocabulary performance could be attributed to the systematic implementation of technology-enhanced vocabulary learning strategies throughout the intervention. First, the digital vocabulary organization and classification strategy helped students build a structured knowledge of specialised terminology by categorizing words into design-related categories such as materials, product features, manufacturing processes, and design principles. This organization may have reduced cognitive overload and enabled students to make stronger links between related vocabulary items. Second, the multimedia contextual vocabulary learning strategy helped students understand specialised terminology by combining verbal information with visual representations, such as product images, video design, and authentic digital materials. With these multimodal resources, students could connect technical terms with real industrial design concepts rather than memorizing isolated definitions. Third, the digital retrieval and spaced practice strategy, especially the Quizlet-based activities and online vocabulary review, offered students repeated opportunities to recall and reuse newly learned terms. These repeated retrieval opportunities likely contributed to better vocabulary retention and accounted for the large increase in post-test performance. Fourth, the technology-enhanced vocabulary

exploration strategy encouraged the use of online dictionaries and digital resources to explore pronunciation, word meanings, word families, and collocations. This process enhanced lexical knowledge and fostered more autonomous vocabulary learning. Lastly, the technology-enhanced productive practice strategy offered students opportunities to use specialised vocabulary in digital presentations, writing tasks, and design-related communication activities. These activities moved students from passive recognition of vocabulary to active use of vocabulary in discipline-specific contexts.

Qualitative data further supported these quantitative results, gathered through interviews and classroom observations. Students reported that digital flashcards, online dictionaries, multimedia materials, and interactive quizzes helped them review vocabulary more often, understand technical terms more clearly, and use specialised vocabulary more confidently. Classroom observations also showed that students were more engaged and participated more actively in technology-supported vocabulary activities.

3.4. Interview Results

Theme 1. Digital Classification for Better Vocabulary Organization and Less Learning Difficulties

Students reported that before the intervention, they had difficulty handling large quantities of specialised vocabulary. Technical terms from various design fields were often learned in isolation, without an organizational system. Students' perceptions of the digital vocabulary organization activities were that organizing vocabulary into categories based on specific design-related topics made it easier to establish clearer relationships among the vocabulary and to improve recall of the specialised terms.

Student A said that digital classification helped to learn vocabulary from different design disciplines: "When I was doing vocabulary work before, it was all mixed up, and I forgot fast. But when I put the words Interior Design, Fashion Design, and Graphic Design in, it was easier and clearer to remember."

The student's answer suggests that implementing digital vocabulary reduced cognitive load by providing a systematic way to store and retrieve specialised terms. Students no longer viewed vocabulary as isolated words but as related concepts within professional categories.

Student B also mentioned the advantages of digital topic-based vocabulary lists for tracking learning progress: The list showed me what I had already mastered and what I still needed to review. I could see my progress step by step. This finding indicates that digital vocabulary management tools helped students become aware of their progress in learning and led to more systematic vocabulary practice.

Theme 2. Improving vocabulary retention through technology-based repetition and retrieval practices

Students said repeated exposure through digital tools helped them overcome one of their biggest struggles — forgetting specialised vocabulary after initially learning it. Rather than traditional vocabulary learning that often relied on memorization before tests, technology-supported activities created opportunities for frequent review and active recall. Students particularly valued digital flashcards, online quizzes, and repeated vocabulary practice, as these activities enabled them to revisit terms they had learned and check their understanding. Student B said: "I learned words once before and usually forgot them after the lesson. "I could practice many times and remember the words longer by the online review activities." Students also found feedback from the digital activities timely and helpful for identifying their mistakes and correcting their vocabulary knowledge on their own. This result is consistent with observational data, which showed greater participation in self-correction during technology-supported practice.

Theme 3. Enhanced Contextual Understanding with Authentic Digital Materials and Multimedia

Another major theme that emerged from the interviews was the role of multimedia resources in helping students to understand specialised vocabulary in meaningful contexts. Students reported that learning design terms through images, videos, and authentic materials was more effective than learning them by translation only.

Student C emphasised the importance of linking vocabulary to professional contexts: "When I see the pictures and examples of the products, I can understand the meaning better because I know how the words are used in a real design situation." Students also recommended more visual materials and real-world design tasks to support additional vocabulary learning. The results show that multimedia-supported learning helped students connect linguistic knowledge to professional concepts, particularly among Industrial Design students.

Theme 4: Greater Confidence and Use of Vocabulary in Design-Related Tasks

The last theme focused on students' growing confidence in using specialised English vocabulary. Students reported that before the intervention, they were reluctant to use technical terms because they were unsure of their meanings and of when it was appropriate to use them. After technology-enhanced activities, students felt more confident using vocabulary in presentations, discussions, and design assignments. Student C said, "Now, I don't just memorise words for the test. I can use these more naturally in day-to-day conversations."

Students also reported that integrating vocabulary practice into listening, speaking, reading, and writing activities supported their ability to apply vocabulary in real communication. They felt more at ease discussing product features, design concepts, and ideas using specialised terminology.

In summary, the interview results showed that technology-enhanced strategies helped shift students' vocabulary learning from passive memorization to more systematic, interactive, and application-oriented learning. Students especially enjoyed organizing vocabulary digitally, retrieval practice (repetition), and multimedia contextual learning, as well as activities involving technology-supported communication. The qualitative data supported the quantitative results, indicating that the intervention contributed to improved vocabulary performance, the development of positive attitudes toward learning, and the empowerment of Industrial Design students' confidence in using specialised English.

3.5. Classroom Observations

Table 7. Classroom observation findings of technology-enhanced vocabulary learning

Theme	Technology-enhanced strategy	Observation evidence
Engagement with digital tools	Quizlet, Kahoot, and online learning platforms	Students actively participated in digital flashcard practice, online quizzes, and vocabulary review activities. They showed an increasing willingness to engage in technology-supported tasks throughout the intervention.
Vocabulary organization	Digital vocabulary lists and classification tools	Students used digital vocabulary records to organise specialised terms according to design-related categories, such as materials, product features, and manufacturing processes.
Contextual understanding	Multimedia resources, including images, videos, and authentic design materials	Students connected specialised terms with visual and professional contexts, which helped them understand the meanings and applications of technical vocabulary.
Vocabulary retention	Digital flashcards, retrieval practice, and repeated online review	Students repeatedly reviewed target vocabulary, checked answers, identified mistakes, and used digital activities for self-correction.
Learner autonomy	Online dictionaries and digital vocabulary resources	Students independently searched for pronunciation, meanings, collocations, and usage examples without relying entirely on teacher explanations.
Vocabulary application	Technology-supported speaking and writing activities	Students applied specialised vocabulary in digital presentations, product descriptions, and design-related discussions with greater confidence.

Classroom observations provided additional qualitative evidence of students' engagement and learning behaviours during the technology-enhanced vocabulary intervention. The findings showed that digital tools were used across multiple stages of vocabulary learning, including vocabulary organization, contextual understanding, retrieval practice, independent learning, and vocabulary application. Six main themes emerged from the observation data, as shown in Table 7. Regarding engagement with digital tools, students actively participated in technology-enhanced vocabulary tasks via Quizlet, Kahoot, and online learning platforms. They were more engaged in digital vocabulary practice and review activities, particularly interactive tasks and online quizzes. Students used digital vocabulary lists and classification tools to organise vocabulary by industrial design topics and categories. This helped them develop more systematic ways of recording and handling technical vocabulary rather than relying solely on word lists. For contextual understanding, the multimedia resources used in learning activities were primarily images, videos, and real design materials. We noticed students linking specialised terms to real industrial design situations, such as product features, materials, and design processes, which helped them understand technical vocabulary. Flashcards and retrieval-based activities for vocabulary retention were repeated in digital review activities. They checked their answers multiple times, identified mistakes, and revised their vocabulary use during online practice activities. Regarding learner autonomy, the observations revealed that

students used online dictionaries and digital tools more often to independently check the meaning, pronunciation, and collocations of words. Students were more actively involved in exploring and verifying vocabulary information rather than depending entirely on teacher explanations. Finally, regarding vocabulary use, students used specialised vocabulary in speaking and writing activities related to technology-supported tasks, such as digital presentations, and design-related tasks. They were more confident using specific vocabulary to describe products, explain design ideas, and convey professional ideas. In general, classroom observations confirmed that technology-enhanced strategies promoted multiple aspects of specialised vocabulary learning. The behaviours observed were consistent with the results of the questionnaire and interview, as digital tools facilitated active engagement, learning in context, vocabulary retention, autonomous learning, and practical application of vocabulary.

4. DISCUSSION

The study was designed to investigate the effectiveness of technology-enhanced strategies for learning specialised English vocabulary among fourth-year industrial design students. Results from the vocabulary test, questionnaire, interview, and classroom observations indicated that the use of digital tools alongside evidence-based vocabulary learning strategies significantly contributed to students' vocabulary growth. Students showed significant improvement in specialised vocabulary performance after the intervention, held positive perceptions of technology-supported learning activities, and shifted their vocabulary learning behaviours from passive memorization to more active, contextualised, and autonomous learning.

The findings extend the existing body of literature on ESP vocabulary learning, demonstrating how technology can serve as a pedagogical tool, enabling vocabulary exposure, organization, retrieval, contextual understanding, and practical application. Rather than treating technology as an auxiliary resource, this research emphasises integrating digital tools with sound principles of vocabulary learning to meet the specific needs of discipline-specific learners.

4.1. Difficulties in Learning Specialised English Vocabulary

The first research question examined the challenges industrial design students face in learning specialised English vocabulary. The findings suggest that the main difficulties students experienced were remembering vocabulary, the large number of technical terms, and understanding specialised vocabulary when it was presented without context.

These results align with previous studies showing that vocabulary learning requires more than one exposure and opportunities to use the new language meaningfully, rather than merely memorizing lists of words (Nation, 2013; Schmitt, 2008). The challenge of ESP specialised vocabulary is that technical terms occur less frequently and are more closely tied to disciplinary concepts. Terms used by Industrial Design students, such as those for materials, product functions, manufacturing processes, and design principles, cannot be understood through literal translation alone and must be interpreted in context in professional situations.

The interviews further illuminated these challenges. In the past, students said they relied heavily on memorizing vocabulary lists but soon forgot the words. This suggests that traditional methods of vocabulary acquisition may not provide sufficient opportunities for deeper lexical processing. Thus, the findings support the need for technology-enhanced approaches that provide repeated exposure, contextualised learning, and active retrieval opportunities.

4.2. Effectiveness of Technology-Enhanced Strategies in Enhancing Vocabulary Performance

The most important finding of this study was the significant improvement in students' performance on specialised vocabulary after the technology-based intervention. Post-test scores were significantly higher than pre-test scores, with a large effect size, indicating that the intervention led to meaningful learning gains.

The integration of several technology-supported strategies can explain this improvement. First, digital vocabulary activities helped students develop more structured vocabulary knowledge. Rather than memorizing words in isolation, students organised vocabulary into categories related to design, such as materials, product features, and design processes. This strategy aligns with research on vocabulary learning, which suggests that organizing lexical information into meaningful networks aids retrieval and retention (Gu & Johnson, 1996).

Secondly, digital retrieval activities, particularly Quizlet flashcards and online quizzes, likely contributed to vocabulary retention. The results align with Roediger and Butler's (2011) argument that retrieval practice strengthens long-term memory because learners actively recall information rather than passively review it. The technology in this study gave students several opportunities to retrieve and reuse specialised vocabulary outside of class time.

Third, multimedia support in vocabulary learning seemed to facilitate students' understanding of technical terms. Mayer (2021) suggests that coupling verbal information with relevant visual displays leads to deeper understanding. This is especially true for students of industrial design, as many specialised concepts are closely related to visual elements, such as product forms, materials, and design processes. The use of images, videos, and authentic design materials helped students relate vocabulary to professional settings.
Thus, the findings suggest that the intervention was successful not merely because of the use of technology, but rather because of the thoughtful integration of digital tools with pedagogically sound vocabulary strategies.

4.3. Students' Views on Technology-Enhanced Strategies for Vocabulary Learning

The second research question examined students' perceptions of technology-enhanced vocabulary learning strategies. Overall, students held positive attitudes toward the intervention, particularly regarding the organization of digital vocabulary, repeated review, multimedia resources, and online learning tools.
The positive perceptions observed in the study are consistent with previous studies showing that technology-supported vocabulary learning can increase learner engagement and offer flexible opportunities for independent practice (Bueno-Alastuey & Nemeth, 2020; Nguyen & Le, 2022). Students particularly enjoyed the digital tools' capacity to enable more frequent vocabulary review, provide pronunciation support, and explore meanings beyond classroom instruction.
The interview findings also indicated that technology helped build students' confidence and autonomy. Students reported that online dictionaries and digital resources enabled them to independently look up meanings, pronunciations, word families, and collocations. This finding supports Benson's (2013) idea of learner autonomy, which highlights the learner's capacity to take responsibility for regulating their learning processes.
Moreover, classroom observations indicated that students' use of digital resources became increasingly independent. Students increasingly use technology to solve vocabulary problems and keep track of their learning progress instead of waiting for the teacher to explain. This suggests that technology-enhanced vocabulary learning may promote vocabulary development as well as the development of autonomous learning behaviours.

4.4.The Role of Technology in the Changing Vocabulary Learning Behaviours

This study not only revealed improvements in vocabulary but also changes in students' learning behaviours. Prior to the intervention, students mainly learned vocabulary through memorization and translation. After the intervention, they exhibited more active behaviours, such as organizing vocabulary digitally, exploring meanings on their own, reviewing vocabulary through retrieval activities, and applying terminology in communication tasks. This is an important finding because learning ESP vocabulary requires learners to move from recognition to actual use. Vocabulary knowledge is not just about knowing word meanings but also about understanding how words function in different contexts (Nation, 2013). The technology-enhanced activities in this study provided opportunities for students to encounter vocabulary repeatedly and to use it in meaningful industrial design contexts.
The combination of technology-supported speaking and writing activities also helped students transfer vocabulary knowledge to productive skills. Students reported greater confidence in describing products, explaining design concepts, and engaging in professional discussion. Technology thus served as a mediator between vocabulary learning and disciplinary communication.

4.5. Pedagogical Implications

The findings of this study have pedagogical implications for ESP vocabulary teaching in higher education across multiple domains. First, technology should not be treated as an add-on to classroom instruction; it should be integrated with established principles of vocabulary learning. Digital tools work best when they support meaningful learning processes: repeated exposure, retrieval practice, learning in context, and opportunities to use vocabulary productively.
Second, ESP teachers should carefully select, and design technology-supported activities based on learners' disciplinary needs. Vocabulary learning for industrial design students should go beyond rote memorization of isolated definitions and include multimedia resources, authentic design materials, online reference tools, and discipline-related tasks that help students connect terminology to professional contexts. Such integration can help learners deepen their understanding and use specialised vocabulary more effectively in academic and workplace communication.
Third, technology-enhanced vocabulary instruction can promote learner autonomy by enabling students to access resources, review vocabulary at their own pace, and monitor their progress. Therefore, teachers should guide students in using digital tools effectively rather than simply introducing technological applications. Clear

directions, appropriate learning tasks, ongoing feedback, and technology that supports meaningful vocabulary development are needed to accomplish this.

Finally, ESP course designers should regularly incorporate technology-enhanced vocabulary activities into specialised language courses. The combination of teacher guidance, digital resources, and active practice of discipline-specific vocabulary can create a more engaging and effective learning environment for discipline-specific learners.

5. CONCLUSION

This study examined the effectiveness of technology-enhanced strategies for improving specialised English vocabulary learning among fourth-year industrial design students. By integrating digital tools with evidence-based vocabulary learning approaches, the study aimed to address students' difficulties with vocabulary retention, contextual understanding, and the practical use of specialised terminology in an ESP context.

The findings demonstrated that technology-enhanced strategies significantly improved students' performance in specialised English vocabulary. The comparison of pre- and post-test results showed a statistically significant increase in students' vocabulary scores after the 11-week intervention, indicating that integrating digital vocabulary organization, multimedia-supported learning, retrieval practice, online resource exploration, and technology-supported productive activities contributed positively to vocabulary development.

In addition to measurable gains in vocabulary, the findings showed that students developed more positive attitudes toward technology-supported vocabulary learning. Students particularly valued digital tools for organizing vocabulary, repeatedly reviewing terminology, accessing contextualised materials, and supporting independent learning. Interview and classroom observation data further indicated that technology transformed students' learning behaviours from passive memorization to more active, contextualised, and autonomous vocabulary practices.

This study contributes to research on ESP and technology-enhanced language learning by demonstrating how digital technologies can be effectively integrated with pedagogical principles to support discipline-specific vocabulary development. In industrial design education, where specialised knowledge is closely tied to visual concepts, professional practices, and authentic materials, technology offers valuable opportunities to connect language learning with disciplinary contexts.

The findings also have practical implications for ESP teachers and curriculum designers. Rather than using technology merely as a supplementary resource, teachers should strategically integrate digital tools into vocabulary learning by applying principles such as contextual learning, retrieval practice, repeated exposure, and opportunities for productive language use. This integration can create more engaging and meaningful learning environments for students who need specialised English for academic and professional purposes.

Despite these contributions, this study has several limitations. The research was conducted with a relatively small group of industrial design students at a single university, and the intervention lasted only 11 weeks. Therefore, future studies should involve larger samples, longer intervention periods, and additional comparison groups further to examine the long-term effectiveness of technology-enhanced vocabulary learning strategies. Future research may also explore the potential of emerging technologies, such as artificial intelligence-supported learning platforms and adaptive vocabulary systems, to support specialised English vocabulary acquisition across different professional disciplines.

In summary, this study suggests that technology-enhanced strategies are a promising approach to improving specialised English vocabulary learning in ESP contexts. When thoughtfully integrated with effective vocabulary-learning principles, technology can support not only vocabulary acquisition but also learner autonomy, confidence, and the ability to use specialised language in authentic professional situations.

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