**INTERACTIVE ONLINE EXERCISES WITH SELF-DIRECTED LEARNING STRATEGIES**

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**Abstract**

 **Practice is essential to improve learners' acquisition of mathematical knowledge and skills. For the freshman Mathematics module in a Polytechnic in Singapore, exercise questions in PDF format have been provided as a form of further practice, which learners solve, after class, in their own time. As technology advances, e-learning platforms can be utilised, along with adaptive learning technology, to enhance learners' engagement in solving these exercise or practice questions.**

 **Our study utilises the in-house creation of interactive online exercises in the Sharable Content Object Reference Model (SCORM) format with the incorporation of self-directed learning (SDL) strategies to improve learners' SDL abilities. A quantitative research design was used to investigate how implementing these SCORM exercises with SDL lesson design strategies impacts learners' SDL abilities, mathematical knowledge, and skills.**

 **Results reveal that learners who attempted six or more SCORM exercises have significantly improved their mathematical knowledge, skills, and SDL abilities.**

**Keywords:** *E-Learning, Adaptive Learning, Self-Directed Learning, SCORM, Mathematics*

**Introduction**

Several scholars assert that practice is critical to improving the ability to solve mathematical tasks (Sigmundsson & Loras, 2013). For example, in two classroom experiments by Emeny et al. (2021), practice spaced out has consistently improved the mathematics test scores of learners in both experiments.

With rapidly evolving technological advances, educational institutions have increasingly used up-to-date technology to teach and learn mathematics. Computer-assisted learning (CAL) is one of them, as it involves using computers to enhance learning via computerised instruction, drills and exercises. De Witte et al. (2015) affirmed the positive impact of the CAL in learning mathematics when they found that schools that frequently used CAL had higher test outcomes. Lai et al. (2015) similarly discovered that remedial CAL outside of regular school hours improved the learner's mathematics scores and increased their interest in learning. Furthermore, a comparison of different interventions for learners with mathematical difficulties showed that computer-based practice effectively improves mathematics proficiency and is a valuable tool for reviewing mathematical concepts taught in earlier lessons (Kanive et al., 2014).

Alotaibi and Alanazi (2021) highlighted that learners with a highly fragmented conception of mathematics tend to have low SDL skills and, in turn, low mathematics achievement. In contrast, learners with a highly cohesive concept of mathematics tend to have high SDL skills and, in turn, high mathematics achievement. Another study that investigated the relationship between three components of SDL in online learning found that motivation directly affected self-monitoring and indirectly influenced self-management through self-monitoring. In addition, self-monitoring positively influences self-management (Zhu et al., 2020). Therefore, equipping learners with mathematical knowledge and SDL skills is vital to enhancing their performance in mathematics.

Despite the recognized benefits and growing interest in using adaptive learning technology in teaching, its broad implementation remains somewhat limited. The review of previous studies shows that higher educational institutions face various barriers and challenges when testing or adopting adaptive learning tools. The main challenges discussed in the literature are related to technology and pedagogy (e.g., Bailey et al., 2018; Johnson & Zone, 2018; Zliobaite et al., 2012). Major technological challenges involve, for example, dealing with real-time data (Zliobaite et al., 2012), difficulties in integrating adaptive learning solutions into existing learning management systems (LMS), the complexity of adaptive systems and their ease of use or usability (Dziuban et al., 2018; Tyton Partners, 2016). Some pedagogical challenges relate to the need to redesign the curriculum (Educause, 2017) and the role of faculty in the adoption process (Oxman & Wong, 2014; Tyton Partners, 2016).

One commonly cited challenge is faculty engagement. When first exposed to the adaptive approach, faculties often resist using technology (Johnson & Zone, 2018). In many cases, faculties express concerns about the benefits of adaptive learning, their diminishing role in a course design, loss of control over courses, and additional workload (Hall Giesinger, 2016; Izumi, Fathers & Clemens, 2013; Johnson & Zone, 2018; Tyton Partners, 2016). In the phase of piloting adaptive learning, faculties often struggle with using adaptive software for communicating with students and modifying learning content (O'Sullivan, 2018). Weber (2019) reflected on the slow adoption progress and concluded that today's primary challenge is the massive investment in time, money and resources resulting from the complexity of adaptive technology. Other concerns include high licensing fees and long-lasting scepticism of faculties towards its potential disruption in education in general.

To address the identified gaps, the project team created carefully selected and curated sets of in-house interactive online exercises using the SCORM format, which is cost-efficient, less time-consuming and less resource intensive. Furthermore, the ownership and direct access to the SCORM exercises afford the creators the flexibility to craft their questions suited towards relevant coverage and address the difficulty across various content segments within the module. Additionally, learners do not need to familiarise themselves with another new platform to attempt these SCORM exercises. Finally, to facilitate monitoring of learners’ progress, the project team developed a dashboard, entailing learners' progress in the SCORM exercises, ensuring easy access for lecturers to monitor learners' progress.

**Methodology**

 This study addresses the following research questions:

RQ1: How do SCORM exercises impact learners' acquisition of mathematical knowledge and skills?

RQ2: How do SDL strategies incorporated in lesson design affect learners' SDL abilities?

 A quantitative research design was employed to analyze the impact of SCORM exercises on the acquisition of knowledge and skills and the learners' SDL competencies across seven dimensions, namely, Assess Task, Evaluate Expertise, Plan Approach, Monitor Progress, Adjust Strategies, Learning Motivation and Collaborative Communication (Vedamuthu & Periasamy, 2022) in the module over the first semester.

 The SCORM exercises featured the following design considerations to help learners with their after-lesson practice:

• Clear instructions highlighting the outcomes, their importance and steps towards achieving them. This aligns with the Assess Task dimension of SDL.

• A plan is provided with a suggested timeline to complete each activity that ranges from easy to difficult. This aligns with the Plan Approach dimension of SDL.

• Hints are provided when learners get their first attempt wrong, and they are given a chance to reattempt the question. This aligns with the Evaluate Expertise dimension of SDL.

• Worked solutions are provided after learners answer each exercise question, regardless of the accuracy of the final answer. In addition, a simple two-item self-evaluation checklist is provided for learners to reflect on whether they met the suggested timeline and achieved the outcomes. This aligns with the Monitor Progress dimension of SDL.

• Learners can attempt a similar question again after answering it incorrectly or proceed to a different one. At the end of the exercise, learners can either review their quiz answers, view a detailed report of the quiz or retry the entire quiz (unlimited attempts). This aligns with the Adjust Strategy dimension of SDL.

• The SCORM exercises were made (1) interesting and relevant, (2) feedback showed relevance to learners' current academic lives and future professional lives, and (3) questions were designed to build on prior knowledge and made to mirror similar competency levels as in the quizzes. This aligns with the Learning motivation dimension of SDL.

 Lecturers received weekly feedback about learners' performances on the SCORM exercises. They viewed these statistics on a dashboard identifying learners requiring additional help or specific topics that need more elaboration.

*Quantitative Methods*

 The SDL skills of the learners were measured using an online survey based on the established 7-factor SDL index, comprising 34 indicators. Figure 1 shows the example of 7 indicators from each of the seven dimensions. A 5-point Likert scale was used in the survey, and data was collected in Lesson 04 and Lesson 12. A total of 1456 learners participated in the first survey, while 1106 learners participated in the second survey. Out of these learners, 727 learners participated in both surveys.

Figure 1: Seven of the indicators in the online survey



 After the completion of each lesson, SCORM exercises covering the lesson's topics were given to learners as further practice. These were not part of the lesson’s deliverables. The SCORM exercises were not graded and did not account for the Continuous Assessment grades of the learners. The SCORM exercise completion rate report was used to track each learner's number of exercises before the Mid-Semester (MSA) and End-Semester Assessment (ESE). For analysis, learners' MSA scores, ESE scores, and raw module scores from all 2383 learners were collected.

 The completion rate of the SCORM exercises was high, with 58% of learners completing six or more exercises before ESE (Figure 2). Figure 3 outlines the data collection timeline.

Figure 2: Completion rate of SCORM exercises



Figure 3: Data collection timeline



 Three independent sample t-tests were carried out for two groups on MSA scores, ESE scores and module raw scores to analyse the impact of the SCORM exercises on learners' academic performance (Table 1). Group 1 completed six or more SCORM exercises, and Group 2 completed three or fewer SCORM exercises.

 Two more independent sample t-tests were done on the raw module scores, consisting of high-performing learners with module grades A, B+ and B, and the other for average / below-average learners with module grades of C+, C, D+ and D (Table 2). This is to investigate the impact of the SCORM exercises on learners with different academic abilities.

 Paired sample t-test was carried out on the two SDL survey scores of learners who have completed six or more SCORM exercises to study the impact of the SCORM exercise on learners’ SDL competencies. Data cleaning was done to remove disengaged responses (Curran, 2015; Huang et al., 2015).

 Normality has been satisfied for all the above tests. An example of the normal Q-Q plot for the raw module score is shown in Figure 4, where the observed values match closely to the expected normal.

Figure 3: Normal Q-Q plot of module raw score



**Results and Discussion**

 Table 1 summarises the findings of the three independent sample t-tests. The learners who completed six or more SCORM exercises (Group 1) had consistently obtained significantly higher MSA scores, ESE scores and raw module scores, respectively, than those who completed three or fewer SCORM exercises (Group 2).

Table 1: Independent sample t-tests on MSA scores, ESE scores and raw module scores

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Group**  | ***N***   | **Mean**   | ***SD***   | ***t***   |
| **MSA score**   | 1\* | 1010 | 66.3  | 14.5  | 15.0\*\*\*  |
| 2\*\*  | 1073 | 55.9  | 17.0  |
| **ESE score**   | 1\*  | 1390 | 70.0  | 10.9  | 13.6\*\*\*  |
| 2\*\* | 757 | 61.4  | 15.4  |
| **Module raw score**   | 1\* | 1390 | 70.8  | 7.78  | 15.2\*\*\*  |
| 2\*\* | 757 | 63.9  | 11.0 |

\*Group 1 completed six or more SCORM exercises

\*\*Group 2 completed three or fewer SCORM exercises

\*\*\**p* < 0.001

 Table 2 shows the comparison between high-performing and average / below-average learners. The independent sample t-tests revealed that learners of all proficiency levels across both clusters who completed six or more SCORM exercises showed improvement in their raw module scores.

Table 2: Independent sample t-tests for high-performing learners and average / below-average learners

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Group** | ***N***  | **Mean** | ***SD***   | ***t***   |
| **Module raw score****(learners who scored A, B+, B)** | 1\* | 739 | 76.4 | 4.91 | 5.51\*\*\* |
| 2\*\* | 199 | 74.6 | 3.76 |
| **Module raw score****(learners who scored C+, C, D+, D)** | 1\* | 645 | 64.6 | 4.34 | 6.69\*\*\* |
| 2\*\* | 498 | 62.7 | 4.97 |

\*Group 1 completed six or more SCORM exercises

\*\*Group 2 completed three or fewer SCORM exercises

\*\*\**p* < 0.001

 Results from the paired sample t-test on the two SDL survey scores (1st survey: M = 4.00, SD = 0.52; 2nd survey: M = 4.11; SD = 0.56) of learners who have completed six or more SCORM exercises indicate that completing SCORM exercises improves the SDL abilities of the learners, t(432) = 4.28, p < .001.

 All results showed that SCORM exercises positively impact learners' acquisition of mathematical knowledge and skills and their SDL abilities, which answered research questions RQ1 and RQ2.

**Conclusion**

 Quantitative results revealed that learners who have completed six or more SCORM exercises have significantly improved SDL abilities and academic performance in mathematics. The development of in-house SCORM exercises has received encouraging feedback from learners, with high completion rates and improved academic performance and SDL abilities. It is recommended that interactive online exercises in SCORM format be included in technical modules (such as mathematics, physics, mechanics, principles of electronics, etc.) to improve learners' academic performance and SDL abilities significantly.

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