Scaffolding to Support Self-Regulated Online Learning

Siew Lee TENG, Academy of Singapore Teachers, Singapore

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Abstract
Recognising that equipping students with digital literacy is crucial for them to navigate online materials and increasing student agency are both important educational goals in the future of learning, this study explored the use of scaffolding to design online learning experiences to support student self-regulated learning through an online course on solving Chemistry data-analysis questions that was developed for student self-study. The learning packages that were designed incorporated different types of scaffolding and strategies to support self-regulated learning, leveraging features in the online learning portal developed by the Ministry of Education, Singapore. The study was conducted in four secondary schools in Singapore. Data were collected from analysis of students' work responses on the SLS portal, pre- and post-test results, and a survey. Findings showed that students were highly responsive to the online learning experiences, which led to enhanced performance on data-analysis items. In addition, findings provided insights into the implications for supporting self-regulated learning when engaging secondary school students in an online learning environment.

Keywords: Scaffolding, Self-Regulated Learning, Online Learning

Introduction

Information technology has become an integral part of our lives, with the use of education technology expanding so quickly in the current education landscape that the traditional mode of teaching and learning with solely paper and pen is no longer the norm. With this, equipping students with digital literacy skills is becoming increasingly important in schools. In Singapore, one of the desired outcomes of education is to nurture independent students with a sense of ownership of their learning (MOE, 2018) and schools can leverage the affordances of EdTech tools available in the Student Learning Space (SLS), an online learning portal developed by the Ministry of Education (MOE) to nurture self-regulated learning in an online learning environment.

Recognising that students at a younger age may not fully appreciate the learning intentions in online learning environments and may require more adult guidance, this study explored the teaching and learning of data analysis skills in the Secondary Chemistry curriculum through online self-regulated learning. The purpose is to gain insights into: (i) online learning of Chemistry data-analysis skills; (ii) leveraging on technology to scaffold student learning in an online environment and (iii) ways to better support students in online self-regulated learning.

Literature Review

Scaffolding and Zone of Proximal Development (ZPD)

Wood, Bruner and Ross (1976) first discussed the importance of scaffolding on the learners' capability in solving problems with the help of adults. Scaffolding is closely related to the learning theory of the Zone of Proximal Development by Vygotsky (1978) which explains that student, with the help of a more knowledgeable other, can perform more complex tasks than they would otherwise be capable of performing on their own. It is about what the learner cannot do, what the learner can do with assistance and what the learner can do unaided.

Greater use of education technology in recent years has added another dimension to how we understand scaffolding in the 21st century education. With technology, the child's interaction with a more knowledgeable adult and/or peer would now include interaction with the content in an online environment.

Scaffolding in Online Learning

In terms of types of scaffolding that are provide effective instructional support for learning in an online environment, Hanaffi, Land and Oliver (1999), and Jumaat and Tasir (2014) presented four types of scaffolding, namely the conceptual, metacognitive, procedural, and strategic scaffolding.

Conceptual scaffolding supports students cognitively to acquire knowledge and perform complex tasks independently that are within the zone of proximal development. This includes concept development, sequence of thought processes and breaking down of complex tasks.

Metacognitive scaffolding guides students to review and assess what they already know or what have learnt. It brings out awareness in learning, to reflect, review and assess how well they have learned, and take a moment to evaluate their progress in the course. Metacognition is an important aspect in self-regulated learning, and metacognitive scaffolding provides opportunities for review, feedback and to support growth.

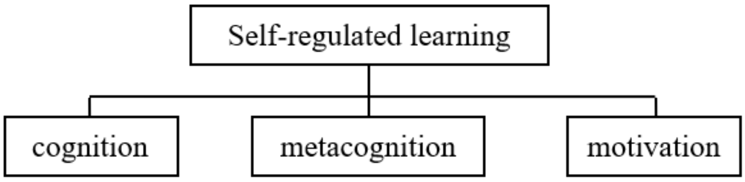
Procedural scaffolding guides students to utilise available resources, materials and tools to complete a task. Procedural scaffolding can play a critical role in ensuring that students can use the tools in the learning management system. This includes the instructions and navigating the Edtech tools in the online portal.

Strategic scaffolding provides guidance and structure about alternative solutions, strategies or options to complete a task, such as offering choices. It often refers to deploying the principles of differentiated instructions when guiding students in working on the task.

Self-Regulated Learning (SRL) and Motivation

Zimmerman (2015) noted how students become masters of their own learning processes. He defines self-regulated students as "metacognitively, motivationally, and behaviourally active participants in their own learning" (Zimmerman, 1990, p. 4). In the 21st century education, it is beneficial to ensure that students are equipped with self-regulated capabilities to empower them to learn for life.

Additionally, Lavi, Shwartz and Dori (2019) found a significant relationship between cognition, metacognition and motivation and self-regulated learning.



Lavi, Shwartz and Dori (2019)

Self-regulated learning occurs in the context of a task the learner is pursuing. Scaffolding is found to play a critical role in enhancing student efficacy and student motivation in learning (e.g., Darasawang and Wiriyakaru, 2013). This is because scaffolding increases the likelihood of student success, and challenges students through deep learning and discovery. Self-regulated learners view themselves as autonomous, competent and confident in their ability to perform. Competence can be supported in well-structured environments that allow for opportunities for growth, positive feedback, and challenges (Ryan and Deci, 2020).

Design of Self-Regulated Online Learning Experiences

The data-analysis in Chemistry online course was developed to enable students to acquire knowledge and skills to solve problems that require handling of information and interpretation in the Upper Secondary Chemistry curriculum. Consideration was given to the following essential elements to promote self-regulated online learning when designing this online course:

(1) Cognition, using conceptual and procedural scaffolding to develop understanding and thinking processes in solving data analysis questions. For example, big ideas of each lesson, simple notes on each skills set, guiding questions, use of *interactive thinking*

tools for crowdsourcing answers as well as the use of practices that mapped to the examples.

(2) Metacognition, tapping on EdTech features such as *tooltips, hints, automated feedback* that promote metacognition. Metacognitive scaffolding such as *reflection*, *think again* and *prompts* to check against success criteria to guide students in learning as the support opportunities for learning and growth.

(3) Motivation, sustaining student motivation and engagement so that they can fully benefit from the online learning. Principles of Differentiated Instruction and Self-Determining Theory were applied, such as setting respective tasks with multi-modal scaffolding (*videos, diagrams*) offering choices for different learning preferences (*audio or text, try first or go through example*), embedding checking in prompters on *challenges*, *encouragement* and *try again* messages.

The Chemistry data-analysis online course includes three lesson packages that are presented in the form of a learning guide. Each lesson covers specific skillsets and success criteria that were worked out from the key skills required in handling data and problem-solving:

Lesson 1: Describing Trend and Relationship, and the Underlying Issues
Lesson 2: Extracting Data for Calculations
Lesson 3: Making Inferences and Deductions

Data Collection and Implementation

The target sample was Secondary Three students from Government secondary schools taking the Chemistry syllabus. The study was implemented in two cycles (i.e., with two batches of students) in four schools with a total of 263 students completed the pre- and post- tests that were administered.

Prior to attending the online course, the students completed a pre-test which covered the data-analysis skills they would learn in the online course. Following that, they were given a duration of about one school term (10 weeks) to complete the online course as part of their Chemistry learning process. Schools could decide if they would like to administer the online course as a fully student self-study module, or with handholding and monitoring by the teacher.

The objectives and timeline of the online course were shared with the students by their teachers. Students in School A were assigned the online course as a fully student self-study while students in schools B, C and D completed the online course with teacher check-ins every two to three weeks to address issues related to navigating the online materials or using the Edtech tools, without actual teaching of the content covered in the online course. Students could raise any challenges faced in the learning tasks while teachers provide self-regulated feedback to all via the learning portal. In-class lessons in class went on as per normal as the teaching and learning of other topics continued and students were given the ownership to decide on how they would plan to complete the assignment, with a recommended timeline given in the online course instructions. At the end of the online course, students had to complete the post- test that was administered.

A student perception survey was also administered separately to gather deeper insights on student engagement and motivation in self-regulated learning, including additional questions to seek students' input on ways to improve the learning experiences of the online course.

Result Analysis

Pre- and Post- Tests

The overall results of the pre- and post- tests are shown in Table 1:

Table 1: Overall Results for Pre- and post- test

Year	2021	2022
N	128	112
p-value	7.50×10^{-21}	1.99×10^{-15}
Cohen's d	0.88	0.89

The paired t-test p-value ≤ 0.05 shows that the intervention is statistically significant and the Cohen's d value > 0.8 indicates a large effect size. The results are consistent for the sample size of 263 students in the two cycles. This result shows that the online course is effectively supports the students' learning.

Individual school's pre- and post- test results were also analysed to gain deeper insights into the study and the details are in Table 2:

Table 2: Results for Individual School's Pre- and Post- test

2021				
School (N)	A* (36)	B (17)	C (41)	D (34)
p-value	2.48×10^{-4} (significant)	7.73×10^{-5} (significant)	9.49×10^{-10} (significant)	2.94×10^{-6} (significant)
Cohen's d	0.545 (medium effect)	0.869 (large effect)	1.08 (large effect)	0.933 (large effect)
2022				
School (N)	A* (28)	B (15)	C (28)	D (41)
p-value	6.25×10^{-4} (significant)	0.128 (non-significant)	6.17×10^{-9} (significant)	3.26×10^{-6} (significant)
Cohen's d	0.302 (small effect)	0.382 (small effect)	1.31 (large effect)	0.907 (large effect)

While students in School A completed the online course on their own with little teacher's guidance, the paired t-test result of School A still reflected a significant p value, with a medium effect in 2021 and a small effect in 2022. This means that the online course has a positive impact on students' acquisition of data-analysis skills despite minimal teacher's guidance. A non-significant effect and a small effect size were obtained for School B in 2022 due to a higher baseline in the pre- test, i.e., students were at a higher starting position and had some data-analysis skills before they started the online course.

The findings from additional data submitted by two other schools (School E and School F), which repeated the data collection process, showed consistent results as shown in Table 3.

Table 3: Results for Two Other Schools' Pre- and Post- test

2023		
School (N)	E* (36)	F (36)
p-value	4.20×10^{-4} (significant)	0.0823 (non-significant)
Cohen's d	0.573 (medium effect)	0.355 (small effect)

The results showed a consistency when students were given the online course to complete on their own with little to no teacher's guidance, the intervention is significant with small to medium effect size (School A in 2021 and 2022, and School E in 2023). While the consistency in the non-significant impact to students with a higher baseline in the pre-test was also clearly reflected in the results (School B in 2022 and School F in 2023).

Student Survey

The student survey that was administered focused on engagement and motivation in terms of students perceived value (V) and ownership (O) in completing the online assignment as well as the clarity (C), access (A) and rigour (R) of the online course in their learning. The results from student survey are collated in Table 4.

Table 4: Results for Students Perception Survey

No.	Question stem	% of students agree and strongly agree	
		2021 (N = 107)	2022 (N = 122)
1 (V)	I understand why I have to do the lesson packages.	98.1	94.3
2 (C)	The instructions in the lesson packages are easy to understand.	93.4	91.0
3 (C)	The success criteria are helpful for me to focus on what is required when answering the type of the questions.	91.6	94.3
4 (A)	The examples help me to understand how to answer the type of questions.	94.4	95.1
5 (R)	The number of practice questions are sufficient to help me learn the skills.	84.2	88.5
6 (R)	The practice questions are good challenges for me.	96.3	94.3
7 (A/C)	The automated feedback is helpful for me to think about how I can better answer the questions.	90.7	92.6
8 (V/O)	I am willing to spend time and effort to do similar lesson packages to learn and practice the skills in problem solving.	93.5	89.3

Results from the student survey showed that in general, the students understood the rationale of the online learning guide for self-study. They felt that the online course was pitched at the right level, was easy to understand and accessible. As such, the online course sustained student engagement, built student competence and confidence, and enhanced their motivation to learn.

Qualitative feedback showed students responded positively to the online course:

> *"It was simple and straight to the point where I can read and understand, then proceed to do on myself."*

> *"The examples on how to do the questions and then giving us the practice questions, which are similar."*

> *"… provided sufficient explanations…"; "videos with clear explanations."*

"Videos and guiding questions are very useful…"; "I liked the hints and examples…"

"I can do it at my own time and own target."; "At my own pace."

"[Can have] more examples on the different type of questions…"

Some examples of students' responses on self-regulated learning process (forethought, monitoring and evaluation) are as follows:

"Try to recall the methods shown [in the examples]."

"I would cross [reference] from the examples given or read the passage again."

"I struggled a lot, but I referred to the practice questions."

"I used the [suggested] answers to check what I may have omitted in my answer."

"I used the PEEL (point elaboration example link) method."

Overall, the online course was well-received by the students, and they were motivated to learn as they saw the value and purpose of the self-regulated learning online course. Regardless of their readiness (including those with higher pre-test baseline), students appreciated the online course in supporting them in acquiring knowledge and/or developing better understanding of answering data-analysis questions. All the data points provided good insights into effective instructional scaffolding to support online learning, which has a significant positive impact on student ability to answer data analysis questions.

Implications for Teaching and Learning

Some insights on good practices in supporting online self-regulated learning are distilled from this study:

(1) There must be clarity in terms of the role of the teacher.
In teaching and learning with technology, student-content interaction needs to be supported by student-teacher interaction to enhance students' learning. Even when setting an online course for students to learn independently, teachers still play an important role in supporting learning, especially for students at the secondary school level. This includes helping students to navigate the online learning materials, use of EdTech tools, helping students to review their learning process, and even sending reminders to complete the work may still be necessary. In addition, teachers need to be mindful of the affective domain of learning, especially to spend time to have conversation with the students on the purpose and learning goals, and checking in how with them on how they feel about the online learning and finding out any issues or challenges they are facing. By doing so, teachers can better guide students to close their learning gaps and increase their motivation by making the task more accessible and achievable.

(2) Student readiness must be considered.
An important consideration for developing students to be self-regulated learners for online learning is student readiness. From the feedback gathered, low readiness students require

additional help, more regular check-ins and teachers' guidance, such as pointing out concept development more explicitly to students and directing them to relevant examples for the practice questions. In addition, some students need more practice to be more confident in mastering the skills. Hence, if the online course is intended for students to acquire skills, teachers can supplement the course by providing more questions for students to check their understanding, while encouraging them to focus on growth and making progress in learning.

(3) Student agency as an outcome must be deliberately planned for self-regulation to take place.

Fostering greater student agency in learning can better sustain student engagement and cultivate good learning habits for students to fully benefit from the online learning. First, through scaffolding that providing successful experiences of mastering in an online environment, students gain confidence and competence, which helps sustain their motivation and engagement in the online tasks assigned. Second, providing opportunities to give students a voice in their learning preferences, such as allowing them to give input to improve the online learning materials, increases student ownership of learning. Teachers could gather feedback from students and make the necessary adjustment as students go through the online learning, instead of making modifications only at the end of the course. Third, student ownership towards self-regulated learning can be developed by guiding them to set goals to complete their assignments, monitor their own learning against the success criteria and self-evaluation of performance focusing on growth. Finally, a collaborative learning environment, where students can support each other and contribute to the discussion of a question or a part of the content from the online course, can be built in both the online learning environment or face-to-face setting.

(4) Technology can promote skills and content acquisition.

This study showed that students were able to develop data-analysis and problem-solving skills beyond the learning of chemistry content via online learning. The use of multimodal instructions such as *text*, *video* and *audio* provide a variation of scaffolding that caters for different learning preferences. Features of Edtech tools such as *interactive thinking tools*, *hints*, and *tooltip* provide metacognitive scaffolding to guide students in checking and monitoring their thinking process, thus helping to facilitate and deepen learning in the SRL process. All these expanded the possibilities to leverage the technology for the teaching and learning of Chemistry via online learning.

Conclusion

The findings from this study showed that providing effective instructional scaffolding supported students in self-regulated online learning. These findings concurred with the study by Baars, Khare and Ridderstap (2022) that effective instructional support is crucial in the SRL process, which include cognitive and metacognitive engagement as well as the importance of enhancing student self-efficacy supported by scaffolding in mastery of the learning.

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