Rodrigo, M. M. T. et al. (Eds.) (2021). Proceedings of the 29th International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Design Guidelines for Scaffolding Self-Regulation in Personalized Adaptive Learning (PAL) Systems: A Systematic Review

Vishwas BADHE*, Gargi BANERJEE & Chandan DASGUPTA
Indian Institute of Technology, Bombay, India
*vishwasbadhe@gmail.com

Abstract: In the present pandemic time, almost all teaching-learning processes have been shifted to online mode. In this online setting, Personalized Adaptive Learning (PAL) educational technology products have become popular amongst educators. PAL systems are facilitating Ubiquitous learning in learner-centric ways by enabling learners to learn anywhere, anytime, at their own pace, and even in settings where teachers are not present (e.g., at home). Such systems require learners to apply self-regulation skills to achieve learning goals. However, guidelines for designing scaffolds for self-regulation in PAL systems for informal (out of school) settings are not readily available. In this paper, we present a systematic literature review of relevant papers published between 2001 and 2021 to understand what guidelines exist. We then propose a set of guidelines that may form the basis for designing effective scaffolds in PAL systems for informal environments for promoting self-regulated learning. The set of proposed guidelines are mapped with 'cyclical phases model' of self-regulation by Zimmerman which will be helpful for PAL system designers.

Keywords: Self-Regulation, scaffolding, ubiquitous learning environments (ULE), Personalized Adaptive Learning (PAL), literature review

1. Introduction

The positive disruption by ubiquitous learning environments in the educational technology domain is experienced by almost all stakeholders in the last decade. A plethora of different Personalized Adaptive Learning (PAL) solutions are being designed by EdTech companies and these are being used by children in ubiquitous learning environments (ULE) which allows seamless mobility in the learning process and is not tied to a specific location. ULE uses a variety of small, portable electronic devices (e.g., smartphones, tablets, smart wearable gadgets, etc.) to create new learning opportunities for learners to learn anywhere, anytime, and at one's own pace (Karoudis & Magoulas, 2016). Such portable environments have seen an increase in use in the present pandemic situation when all teaching-learning processes have shifted to online mode, irrespective of the level of readiness of parents and children. In this online setting, Personalized Adaptive Learning (PAL) educational technology products have become especially popular amongst educators. PAL systems are facilitating Ubiquitous learning (U-learning) in learner-centric ways by enabling learners to learn anywhere, anytime, at their own pace, and even in settings where teachers are not present (e.g., at home). Such systems adapt content and/or assessments based on the learner's performance and interaction with the given resources. To make this process effective, such ubiquitous and adaptive systems require learners to apply self-regulation skills to achieve the learning goals (Leonor & Alejandro, 2019). Self-regulation is defined as the control that learners have over their cognition, behavior, emotions, and motivation through the use of personal strategies to achieve the goals they have established (Panadero & Alonso, 2014). However, to help learners practice self-regulation, sufficient scaffolding is required. But to design scaffolding to SRL in PAL based informal (out of school) ULE systems settings the required guidelines are not available. This paper analyses relevant publications between 2001 and 2021 to present a systematic literature review of existing guidelines. We then propose a set of guidelines that may form the basis for designing effective scaffolds in PAL-based ULE systems for informal environments for promoting self-regulated learning. The following research questions guide our review process- 1) What are the existing design

guidelines for scaffolding self-regulation in PAL-based ubiquitous learning environments?, 2) Which of these guidelines have empirical evidence of their effectiveness? and 3) What are the potential pedagogical and technological operationalization of design guidelines for scaffolding self-regulation in PAL-based ULE for K-12 learners ?

2. Methodology

2.1 Search Keywords & Articles

We identified keywords based on the identified domain to search for potential research papers. The search keywords for ubiquitous environments were "ubiquitous learning environments" or "U-Learning" or "ubiquitous technology in learning". The search keywords for self-regulation are "Self-regulated learning" or "SRL in children" or "SRL in mathematics" or "SRL for academic achievements". The search keywords for scaffolding are "support in SRL" or "parental support in SRL" or "parental support for children" or "scaffolding in SRL". The search keywords for exploring models of self-regulation and its comparative analysis are "SRL models" or "Review of SRL models" or "Comparison of self-regulated learning models". The scope of this review is limited to the past decade i.e., 2001 to 2021.

We searched research databases such as IEEE xplore, Science Direct, Google Scholar to find the relevant research papers. The following inclusion criteria were applied to select the research papers that were found most relevant to our objectives. We considered the papers that included at least meta-level guidelines or provided empirical evidence for the effectiveness of design guidelines for scaffolding in SRL-enabled PALs. The papers which were suggesting some general scaffolding in the classroom or suggesting some parental scaffolding external to PAL were excluded as per exclusion criteria. These inclusion and exclusion criteria were applied to effectively investigate the design guidelines for scaffolding in the self-regulation process. In the initial search using the specified keywords, we have found a total of 679 research papers. Out of 679, we have selected 24 broadly relevant research papers after applying inclusion criteria. After reviewing those 24 research papers, we have found 7 research papers closely aligned with our review objectives.

3. Literature review

3.1 Mapping with SRL Model

To map the design guidelines to the standard SRL models, this study reviewed different SRL models such as the cyclical phases model by (Zimmerman & Moylan, 2009), (COPES) Winne's SRL model adapted (Winne & Hadwin, 1998). After getting insights from different SRL models, the cyclical phases model by Zimmerman & Moylan (2009) was selected because it has strong connections with social cognitive theory as compared to the COPES model. Zimmerman's model (Figure 1) also lays more emphasis on the influence of motivation on self-regulation (Panadero & Alonso, 2014) which is an important parameter for children. On the other hand COPES model has a loosely sequenced learning cycle and it does not depict the social cognitive theory precisely (Rovers et al., 2019). Social cognitive theory is important because SRL occurs through the interdependence of individual aspects, linked to feelings, emotions and thoughts, behavior, and the environment in which students find themselves (Zimmerman, 2000). With the help of social cognitive theory, we can assign meaning to learners' behavior while the learner is using SRL skills.

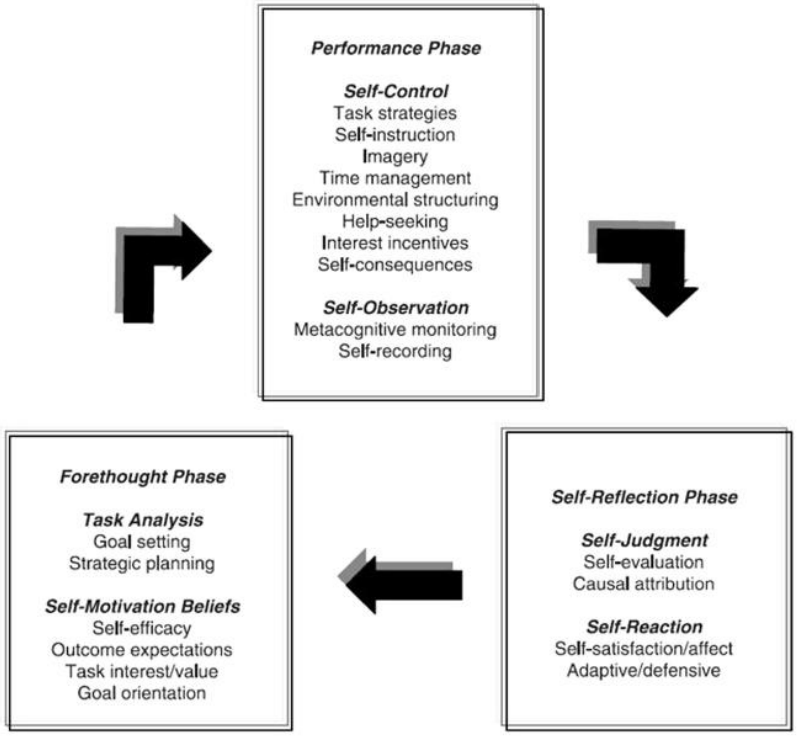

Figure 1. Cyclical Phases Model of Self-regulation according to Zimmerman & Moylan (2009).

Mapping of the existing design guidelines to Zimmerman's model is presented in Table 1.

Table 1. *Existing Design Guidelines for Scaffolding and Its Potential Pedagogical & Technological Operationalization*

Alignment with phases of SRL model by Zimmermann	Design guidelines of SRL	Paper proposing the guidelines	How paper is operationalizing guideline in SRL (supporting arguments for operationalization of SRL)	Potential operationalization for scaffolding SRL in PAL	
				Pedagogical	Technological
Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: have the students set simple, but realistic goals for the pre-class sessions. Support: Have students set a learning goal for a next pre-class session based on their performance in a previous pre-class session	(Yoon et al., 2021)	Allowing the students to set learning goals leads them to initiate the recursive self-regulated learning process toward attaining their ultimate goals. It is important to make the students begin with simple, but realistic goals so that they can have the opportunity to calibrate their goals as they progress. The students' self-efficacy, fostered by their success in prior performances, will, in turn, affect their later self-set goals (Yoon et al., 2021, p. 4)	Computer-based learning environments may facilitate the individual goal setting template in which learners will set their next pre-class learning goals.	Dynamic planning template attached with calendar with timely reminders and appreciation notes. It is the completion of a learning goal which will tell them distance from goal

Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Foster student motivation by highlighting task values. Support: Have the students ponder ways to transfer what they learned from the pre-class sessions to new contexts	(Yoon et al., 2021; Laere et al., 2015)	Students are required to acquire foundational knowledge by studying the given materials at home without the instructors' explanations as to why the materials are useful (i.e. utility value) and what benefits they can have when they successfully complete the task (i.e. attainment value) (Yoon et al., 2021, p. 5)	From the starting point of the lesson, keep learners informed about the rationale and objective behind learning that topic. (task value)	A kind of pre-test can be designed with open ended answers to reflect upon task value questions
Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Scaffolding by parents	(Zhang & Whitebread, 2017)	Parents provide adequate metacognitive information in an understandable way and at an appropriate pace along with task-oriented-ness (Zhang & Whitebread, 2017, p. 2)	Support to parents should be provided for the following points: 1) To effectively integrate ULE in their child's learning process at home. 2) To make parents aware of their child's learning behavior to enhance task oriented-ness like encouraging a child to do problem-solving, selection and decision-making	The possible ways a learning system can address the above is to make actionable performance analysis report of their child available to parents in regular intervals like weekly reports along with learning behavioral pattern
Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Scaffolding to parents	(Muhammad & Iqra, 2020)	Parental autonomy support to learners (Muhammad & Iqra, 2020, p. 2)	PAL in ULE can facilitate opportunities for parents to give autonomy to learners using separate guidelines provided on the parental dashboard	For this, the learning system should give autonomy to learners to choose which chapter, which learning units to do, at what grade level and in what sequence
Performance phase: imagery, metacognitive monitoring	Guideline: Organize instruction and activities to facilitate cognitive and metacognitive processes	(Ley & Young, 2001; Laere et al., 2015)	Overt or covert rearrangement of instructional materials to improve learning (Ley & Young, 2001, p. 2)	Organizing strategies like concept mapping, schematizing (arranging contents in a schematic form) can be implemented	Introduce concept map, concept board or Miro board tool to learners for an activity in which organizing/ relating the content is required

Performance phase: imagery, metacognitive monitoring	Guideline: Use instructional goals and feedback to present the learner with monitoring opportunities	(Ley & Young, 2001)	Record events or results to check its alignment with goals & then feedback can be created (Ley & Young, 2001, p. 2)	Periodic constructive feedback and potential pain points can be highlighted by the PAL and presented before learners. Specific highlights for monitoring can help learners and save their time	Tools for monitoring and checking alignment with goals can be introduced. which checks the consistency of progress with goals and generates correct feedback as required
Performance phase: imagery, metacognitive monitoring	Guideline: Guide learners to prepare and structure an effective learning environment	(Ley & Young, 2001)	Select or arrange the physical setting to make learning easier (Ley & Young, 2001, p. 2)	1) Ask to list the distractions around learners. 2) Advise learners how to arrange physical environments and cope with distractions. 3) Providing a list of strategies will assist less self-regulating learners	Provide a checklist template of guidelines to be followed for setting up the learning environment. This can be followed by the learner
Performance phase: imagery, metacognitive monitoring	Guideline: Help the students accurately monitor their engagements in the pre-class sessions. Support: Use visualizations that show learning activity completion after each pre-class session; use visualizations to show both student progress and performance.	(Yoon et al., 2021)	Allow students to monitor their own learning progress through a support to SRL that visualizes their online behaviors using their log data. The study revealed that the opportunity to obtain information about their learning progress had a positive impact on the students' academic performances (Yoon et al., 2021, p. 4)	1) At the end of each week or fortnight, learners should be provided an opportunity to monitor their own progress so that they can understand their own learning process. 2) After the task, self-report questions	1) Through log data, scores and decisions they have made could be shown using a dashboard so that they can monitor. 2) Tech tool for self-report questionnaire
Self-reflection : self-evaluation, self-satisfaction/ affect, adaptive, defensive	Guideline: Provide learners with continuous evaluation information and occasions to self-evaluate	(Ley & Young, 2001)	Evaluate completed work quality; reread tests to prepare for class (Ley & Young, 2001, p. 2)	Evaluation could not be only comparison between the learner's own performance to a standard, but for comparative outcome between performance and the set standard using them for self-judgment.	Technological options for setting and adjusting evaluation standards and goals can help.

Self-reflection : self-evaluation, self-satisfaction/ affect, adaptive, defensive	Guideline: Scaffold design guidelines: 1) Diagnosis, 2) Calibrated support, 3) Fading, 4) Individualization (Personalized & Adaptive scaffolds)	(Azevedo & Hadwin,2005; Chen, 2014)	Identifying needs and providing correct support till the learner gets mastery (Azevedo & Hadwin, 2005, p. 5)	Continuous diagnosis is required to calibrate/adjust the support of learners.	Remedial scaffolding agents: visualizations, animations, videos, games etc.

Research questions 1 and 2 are addressed in the above table (Table 2) by giving existing design guidelines for scaffolding self-regulation in PAL-based ULE. The first 2 columns are addressing RQ 1 by providing existing design guidelines and mapping with Zimmerman's SRL model. To address RQ 3, in the last two columns, we have tried to propose potential pedagogical and technological operationalization of design guidelines for scaffolding self-regulation in PAL-based ULE for K-12 learners. All research papers reviewed have given empirical evidence for the effectiveness of design guidelines that addressed RQ 2.

The design guidelines for scaffolding SRL given in table 2 above are mapped with Zimmerman's cyclical phases model. Those 3 broad phases are forethought, performance & self-reflection. These broad phases are further divided into micro-level sub-processes. In the forethought phase, learners analyze tasks, set goals, and plan to achieve the goal using different motivational strategies. In the performance phase, the learner executes tasks and monitors one's own progress, and further uses self-control strategies. In the self-reflection phase, learners assess one's own performance and attribute it to levels of success (Panadero, 2017).

4. Recommendations for pedagogical and technological scaffolding in PAL

Based on the literature survey highlighted in table 1, the recommendations for pedagogical & technological scaffolding for PAL-based ULE systems are given in the following table 2.

Table 2. *Pedagogical & Technological Scaffold Recommendations for PAL*

Alignment with phases of SRL model by Zimmermann	Existing Design Guidelines for SRL	Pedagogical & technological scaffolding recommendations for PAL
Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Have the students set simple but realistic goals for the pre-class sessions. Support: have students set a learning goal for the next pre-class session based on their performance in a previous pre-class session.	Enable adjustment of learning goals in ULE: Facilitate goal setting option for learners using dashboard in PAL ULE.
Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Foster student motivation by highlighting task values. Support: have the students ponder ways to transfer what they learned from the pre-class sessions to new contexts.	Provide an opportunity to transfer learning to real-life: Facilitate knowledge construction using a constructivist approach and facilitate objectively correct formative assessments for learners.
Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Scaffolding by parents	Provide Learner autonomy: Equip learner with autonomy support to select learning content as per his/her goal and perception towards task value.

Forethought: Goal setting, outcome expectations, task interest/ value, goal orientation	Guideline: Scaffolding to parents	Provide Parent support: Provide support for parents by which effective adoption of PAL in their child's learning becomes easy and parents could know the learning behavior of their child.
Performance phase: imagery, metacognitive monitoring	Guideline: Organize instruction and activities to facilitate cognitive and metacognitive processes	Provide Instructions in Constructive Approach: Facilitate instructions in a constructive way so that learners could build upon previous knowledge
Performance phase: imagery, metacognitive monitoring	Guideline: Use instructional goals and feedback to present the learner with monitoring opportunities	Provide Motivational features: Include features that motivate the learner intrinsically and extrinsically to explore the content
Performance phase: imagery, metacognitive monitoring	Guideline: Guide learners to prepare and structure an effective learning environment	Provide supporting guideline to structure the environment: To structure one's own learning environment and cope with distractions (checklist)
Performance phase: imagery, metacognitive monitoring	Guideline: Help the students accurately monitor their engagements in the pre-class sessions. Support: Use visualizations that show learning activity completion after each pre-class session; use visualizations to show both student progress and performance	Provide planning & monitoring for self-regulated learning : Provide sufficient guidance for planning and monitoring one's own learning on the PAL dashboard
Self-reflection-self-evaluation, self-satisfaction/affect, adaptive defensive	Guideline: Provide learners with continuous evaluation information and occasions to self-evaluate	Provide continuous real-time information for complementing self-evaluation: To reflect on one's learning, the technological dashboard could provide real-time information about learning in self-evaluation
Self-reflection-self-evaluation, self-satisfaction/affect, adaptive defensive	Guideline: Scaffold design guidelines: 1) Diagnosis, 2) calibrated support, 3) fading, 4) individualization	Provide self-reflection scaffolding to the learner through design: To gain the correct understanding of the topic and relate it to real-life situations. But remove scaffolding slowly when learners get mastery in a skill

5. Discussion

In this paper, we have reviewed prior research on scaffolds for facilitating self-regulated learning in PAL-based ULEs. The design guidelines for scaffolding self-regulation in PAL-based ULEs that emerged from this work show that such scaffolds should provide learners autonomy to select learning content as per their goal and perception towards the value of the task. Sufficient guidance for planning and monitoring one's own learning is imperative in such systems. This can be implemented in the form of a dashboard with the real-time progress of the learner. Such real-time dashboards could nudge learners to become more responsible, self-regulated, and autonomous learners. In addition, with the aid of such dashboard scaffolds, learners will likely gain a deeper conceptual understanding of the topic as they can deliberate on which parts to should pay more attention to. Furthermore, instructions delivered

in a constructive way can help learners build on their previous knowledge and relate to real-life situations. Along with that, motivational support and increased involvement of parents with the help of integrated parent modules can help learners engage in self-regulated learning.

One of the unique contributions of this work is mapping the guidelines to different phases of SRL based on Zimermann's cyclical phases model. Thus, these guidelines inform the ULE designers of the scaffolds required for supporting the flow of SRL. Some guidelines may appear counterintuitive to PAL-based ULE systems but these are important to consider as well. For example, support for parents is essential for making them aware of their child's learning behavior and to effectively integrate ULE into the child's learning process. Such parental supports will likely lead to better self-regulated learning amongst the learners. These guidelines can act as a stepping stone to decide what pedagogical and technological recommendations to include in a ULE. For instance, dashboards can have actionable information on learner progress and performance. In addition, they can also have additional sections to address planning and monitoring of goals attained.

6. Conclusion

PAL-based ULEs are systems that are meant to model an individual learner's learning behavior and construct a personalized learning path on behalf of the learner. Yet learners need to be provided a level of autonomy to set their goals along with provision for re-adjustment of their goals after self-reflection on their performance. This underlines the importance of the above set of guidelines for ULE system designers. These guidelines provide the foundation on which further detailed scaffolding features and standards can be developed. Scaffolding self-regulation in ubiquitous learning environments (ULE) will help learners learn anywhere, anytime, and also in the most suitable way to achieve their learning goal. This could be a way forward to cope with learning losses due to school closure and lack of teacher-learner interaction happening in the current pandemic situation.

Acknowledgments

We would like to thank all the people who have supported the process of review and paper writing.

References

Karoudis, K. & Magoulas, G. (2016). Ubiquitous Learning Architecture to Enable Learning Path Design across the Cumulative Learning Continuum. *Informatics, 3*(19), 10.3390/informatics3040019.

Leonor, A. C. R. & Alejandro, P. (2019). A holistic self-regulated learning model: A proposal and application in ubiquitous-learning. *Expert Systems with Applications, 123*, 299-314.

Panadero, E. & Alonso-Tapia, J. (2014). How do students self-regulate? Review of Zimmerman's cyclical model of self-regulated learning. *Anales de Psicología, 30*, 450-462.

Panadero, E. (2017). A Review of Self-regulated Learning: Six Models and Four Directions for Research. *Frontiers in Psychology, 8*, 10.3389/fpsyg.2017.00422.

Rovers, S., Clarebout, G., Savelberg, H., de Bruin, A., & Van Merrienboer, J. J. G. (2019). Granularity matters: comparing different ways of measuring self-regulated learning. *Metacognition and Learning, 14*, 10.1007/s11409-019-09188-6.

Van Laere, E., McKenney, S., & van Braak, J. (2015). Design guidelines for computer-based learning environments aimed at fostering knowledge acquisition in linguistically diverse contexts. *Technology Research & Development.*

Chen, C. (2014). An adaptive scaffolding e-learning system for middle school students' physics learning. *Australasian Journal of Educational Technology, 30*(3), 342–355. doi: 10.14742/ ajet.430

Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning And Metacognition – implications for the design of Computer-based scaffolds. *Instructional Science, 33*(5-6), 367-379. doi:10.1007/s11251-005-1272-9

Ley, K. & Young, D. (2001). Instructional principles for self-regulation. *Educational Technology Research and Development, 49*, 93-103. 10.1007/BF02504930.

Muhammad, S. F. & Iqra, A. (2020). Parental Involvement as Predictor for Self-regulated Learning and Academic Achievement of Students at Secondary School Level. *Journal of Educational Sciences & Research*, *7*(1), 14-32.

Yoon, M., Hill, J. & Kim, D.(2021). Designing supports for promoting self-regulated learning in the flipped classroom. *Journal of Computing in Higher Education*. 10.1007/s12528-021-09269-z.

Zhang, H. & Whitebread, D. (2017). Linking parental scaffolding with self-regulated learning in Chinese kindergarten children. *Learning and Instruction, 49*, 121-130. 10.1016/j.learninstruc.2017.01.001.

Zimmerman, B. J. (2000). Attaining self-regulation. A social cognitive perspective. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), Handbook of self-regulation (pp. 13-39). San Diego, Ca: Academic Press.

Zimmerman, B. J., & Moylan, A. R. (2009). Self-regulation: Where metacognition and motivation intersect. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), Handbook of Metacognition in Education (pp. 299-315). New York: Routledge.

Winne, P. H., and Hadwin, A. F. (1998). "Studying as self-regulated engagement in learning," in Metacognition in Educational Theory and Practice, eds D. Hacker, J. Dunlosky, and A. Graesser (Hillsdale, NJ: Erlbaum), 277–304.