Measurement Tools that Both Measure and Promote Technology Assisted Self-Regulated Learning

Bor-Chen Kuo[1,2], Frederic Tao Yi Chang[1], and Magdalena Mo Ching Mok[1,3]

[1] *National Taichung University of Education, Taiwan*
[2] *Department of Information and Technology Education, Ministry of Education, Taiwan*
[3] *The Education University of Hong Kong, Hong Kong*

Email: snoopyfred@kimo.com

Introduction

With the rapid changes in society, self-regulated learning (SRL) is an indispensable skill for succeeding in life, work, and citizenship on the 21st century (Dede, 2010). Local and overseas research show that SRL ability is associated with academic achievement (Cleary et al., 2021; Dignath & Büttner, 2008; Kistner et al., 2010; Kizilcec et al., 2017; Kuo, 2018; 2019; 2020; Schmitz & Perels, 2011; Perry & Winne, 2006; Zheng, 2016). Accurate measurement of SRL is essential for educators to formulate appropriate strategies for the promotion and facilitation of SRL skills among learners. Panadero et al. (2016) observed that approaches to measuring SRL capacities changed along with advancements in the conception of SRL and that we were in the third wave of measurement whereby measurement needed to not only assess but also to promote SRL skills. Using a quasi-experiment, the current study explores effectiveness of the Cross-grade Diagnosis (縱貫測驗) in the Taiwan Adaptive Learning Platform (TALP, 因材網) in measuring and promoting SRL amongst primary students needing remedial instruction. Results of this study will inform educators on the effectiveness of Cross-grade Diagnosis as against conventional testing methods in facilitating students' self-regulated learning and academic achievement. For educational software developers, the study will illuminate characteristics of enabling features in the design of technology-assisted learning systems that can give best support for students.

Background

SRL refers to the self-directive learning processes whereby the learner initiates and sustains in order to attain their academic goals (Zimmerman, 2000). A self-regulated learner is one who actively takes care of their own learning towards achieving their learning goals (Zimmerman, 2008). SRL involve a complex interplay among the cognitive, metacognitive, behavioural, motivational, affective, and emotional aspects of the learner as well as the contextual and environmental variables during learning. It is therefore not surprising that over the years, as highlighted by meta-analyses (Dignath & Büttner, 2008; Panadero, 2017; Sitzmann & Ely, 2011), many models (e.g., Boekaerts & Corno, 2005; Efklides, 2011; Hadwin & Oshige, 2011; Pintrich, 2000; Zimmerman, 2000) of SRL have been put forward by researchers, each grounded on different theoretical underpinnings and thus focussed on different aspects of self-regulated learning. Nonetheless, common to all models is the acknowledgement that the nature of SRL is cyclical and iterative, involving phases, processes and strategies in goal setting, strategy selection, progress monitoring, and self-reflection and self-regulation.

Given the complexity of SRL, which is an internal process and cannot be directly accessed, its measurement has not been easy (Boekaerts & Corno, 2005), and various methods including self-report, think aloud protocols, classroom observations, microanalytic measures, data mining and learning analytics have been reported in the literature (Araka et al., 2020). According to Panadero et al. (2016) these assessment methods can be classified into three waves, which reflect researchers' changing conception of SRL. In the first wave, self-regulation was conceived as a trait of the learner and therefore measured using self-report methods such as questionnaire and interviews. The drawback of self-report methods is that SRL process is difficult to articulate and learners might not be accurate in, or even aware of, the strategies they use (Boekaerts & Corno, 2005). Further, changes in learner's strategy use cannot be captured by static measures. In the second wave, self-regulation was conceived as a dynamic process of behavioural, cognitive, metacognitive, motivational, and emotional events within a learner, and its measurement is undertaken from a process perspective (Winnie & Perry, 2000), including such stealth assessments as log data and learner traces collected during learning. Whilst these unobtrusive methods assess SRL objectively at real time, the measurement itself does not promote SRL skills. According to Panadero et al. (2016), we are in the third wave whereby measurement should both assess and promote SRL skills. The

study reported here aims to explore the effectiveness of Cross-grade Diagnosis in TALP as an intervention on promoting SRL skills and academic achievement in addition to assessing these variables.

Relevant Theories

Zone of Proximal Development

Vygotsky's (1978) concept of Zone of Proximal Development (ZPD) describes how a child can go from his/her current development level to a higher potential level through continuous consultation with such other more capable persons as teachers, parents, or peers. The Zone of Proximal Development (ZPD) refers to the gap between what a child can learn independently and what he/she can learn with support from a more knowledge adult or peer (Vygotsky, 1978). Although development can be promoted by engaging the learner in activities beyond his/her actual level of development and scaffolding the learner in performing the new tasks, Vygotsky alerted that, for meaningful learning to take place, the new activities should be linked with the actual level of development of the learner instead of going too far ahead of the learner (Oers, 2020). In other words, the notion of ZPD is not a fixed characteristic of the learner, but is a range of tasks in which the learner aspires to take part, and is able to participate by drawing from his/her already established abilities, but cannot yet accomplish all the tasks on his/her own. With guidance from a more skilled person, the learner masters the tasks and develops a sense of ownership and personal agency as the new activities make sense to the learner.

In the study reported here, Cross-Grade Diagnosis in TALP is used to help students to identify their ZPD (Vygotsky, 1978). For low-achieving students, on-grade learning materials/tasks can be overwhelming and impossible to learn. Through Cross-Grade Diagnosis, ZPD of individual students are identified. In this way, if a student is found to be operating at a grade level lower than the one at which the student is currently enrolled, the teacher can design instructions which better align with the specific ability level of the student and thus enable the student to learn.

Feedback

Feedback is central to self-regulated learning (Butler & Winne, 1995; Labuhn et al., 2010; Zimmerman, 2000). Self-regulation involves learners who take charge of their learning by proactively directing their behaviour and regulating their thoughts and feelings in order to achieve their self-set learning goals. Throughout the cyclical process of goal setting, strategy selection, performance self-monitoring, self-reflection and self-regulation, feedback generated from the previous phase or process is used to adjust behaviour and strategies in the following phase or process of learning (Zimmerman, 2000).

As learners monitor their engagement with tasks, internal feedback is generated when the learners compare the gap between the actual and the targeted outcomes. External feedback is provided by another person, usually the teacher or peers, when the learning yields observable learning products (Butler & Winne, 1995). On basis of the feedback information, the learners may either continue with their pursuit, modify their learning tactics to closing the gap, or modify their learning goals altogether. The monitoring-feedback-regulation process is recursive and continues throughout the learning. It is crucial for the learners to accurately perceive and understand the feedback for it to be impactful on learning (Harks et al., 2014; Labuhn et al., 2010).

Adaptive assessment is implemented and instant feedback is provided in this study to facilitate students' diagnosis of the current status of their acquired knowledge as well as the strengths and weaknesses of their learning (Wu et al., 2017). The most optimal method for learners is to gain instant feedbacks, especially acquiring the diagnosis of their learning weakness immediately to adjust either goals or strategies (Proske et al., 2011). Further, the subject knowledge structure is presented explicitly in TALP such that the student and the teacher both have a clear road map of the student's current knowledge status vis-à-vis the desired outcome.

Your Research Methods And Work

The study reported here is part of a larger project on the Taiwan Adaptive Learning Platform (TALP) sponsored by the Taiwan Ministry of Education. In the current study, the effectiveness of Cross-Grade Diagnosis in TALP for remedial instruction in mathematics of primary students in Taiwan is investigated using a quasi-experimental design. The TALP platform organises learning materials as a hierachical concept network, in which higher level concepts are prerequisite for lower ones (Wu et al., 2017; Yang et al., 2021), and the platform makes use of an adaptive diagnostic assessment system (Ting & Kuo, 2016). The knowledge hierarchical network and the associated diagnosis are cross-grade in design. The cross-grade diagnosis identifies the students' current ability level and facilitates alignment of students' level of knowledge with the level of materials to be learned. In this way, materials are selected around the ZPD (Vygotsky, 1987) of individual students to facilitate their learning. Wu et al. (2017) reported high effectiveness and efficiency of order theory algorithms on knowledge structure

for adaptive testing in that there was 90% accuracy in identifying learning weakness, and it saved about 80% items in the assessment. Empirical study by Ting and Kuo (2016) found that adaptive dynamic assessment offered the best instructive effect compared to either self-study or traditional remedial instructions.

The study sample comprised 991 primary grade students who did not pass the National Screening Test (篩選測驗) in mathematics administered by the Taiwan Ministry of Education in May 2020. These students needed to undergo remedial instruction on mathematics. Teachers made the decision on whether the Cross-grade Diagnosis or the Conventional testing, both available in TALP, was used for the individual students' remedial instruction. After six months, in December 2020, the two groups of students were assessed and compared, (a) using MANCOVA on their SRL skills as measured by the Self-Regulated Learning Integrated Questionnaire (Kuo et al., 2020), and (b) using ANCOVA on their academic performances as measured by the National Progress Test. Results showed that students who had undergone Cross-grade Diagnosis for remedial instruction had better SRL skills and better performance than their counterparts whose remedial instruction was through Conventional testing.

Real World Applications

The TALP is available freely to all primary students in Taiwan. Teachers are free to select either Cross-grade Diagnosis or conventional testing methods within TALP for remedial instruction. Results of this study will facilitate teachers in making evidence-based decisions when designing remedial instructions for their students.

Future Directions

Items in traditional testing are confined to curriculum materials within a certain grade level. In contrast, the Cross-grade Diagnosis in TALP measures students' knowledge level by adaptively assessing the student with items from the current as well as lower or higher grade levels. The benefit of assessing students with items at a different grade level is that it enables the ZPD of individual students to be gauged, and the teacher can use this information to tailor instruction that optimally targets specific strengths and weaknesses of individual students. Previous studies (Wu et al., 2017; Yang et al., 2021) found Cross-grade Diagnosis effective in promoting academic performance of low-achieving students. As TALP is knowledge-structure based, each student in consultation with the teacher can make use of the Cross-grade Diagnosis results to identify his/her own learning paths on the knowledge-structure map in TALP, and select the appropriate online learning materials and instructional videos that aligns with his/her ability level for remedial support. Without doubt accurate measurement is fundamental to understanding students' SRL states but educators need to go beyond measurement and make use of the measurement data to enhance students' SRL capacity and academic learning. This study demonstrated how the measurement-intervention couple can be beneficial for boosting both SRL skills and academic performance of students needing remedial instruction in mathematics. The study capitalised on the relatively well-defined hierarchical knowledge structure of concepts in mathematics. Would the measurement-intervention couple be as effective for remedial instruction in domains (e.g., Chinese language) with less well-defined hierarchy in their knowledge structure? Future research might explore replication of this study in such other domains.

Further, it should be noted that in this study, teachers made the choice of whether Cross-grade Diagnosis or conventional testing was to be used for students' remedial instruction. Nonetheless, recent studies found that SRL instruction was only rarely implemented in classroom or as school-wide policy (Kistner et al., 2010), and that teacher professional development only had little effect in changing teachers' beliefs regarding importance of SRL or enhancing their SRL self-efficacy (Heirweg et al., 2021). Future research is recommended on exploring in greater depth contributing factors to success or otherwise of Cross-grade Diagnosis in relation to teachers' pedagogical content knowledge as SRL agent. Findings from this future research will inform teacher educators on designing professional development programmes on the application of Cross-grade Diagnosis for the promotions of SRL capacity and academic performance of students.

Summary

This study provides empirical evidence on the effectiveness of Cross-grade Diagnosis for measuring SRL and academic achievement of students while affording intervention that promote development in these areas. Our results have practical implications in at least two ways. Firstly, results of this study will inform educators on the effectiveness of Cross-grade Diagnosis as against conventional testing methods in facilitating students' self-regulated learning and academic achievement. Secondly, for educational software developers, the study will illuminate characteristics of enabling features in the design of technology-assisted learning systems that can give best support for students.

ACKNOWLDEGEMENTS

We would like to the Taiwan Ministry of Education for funding this project.
Support from the following colleagues is gratefully acknowledged:
Professor Tai-Chien KAO, *National Dong Hwa University*
Dr Stanley HO, *The Chinese University of Hong Kong*
Ms Mei-Fan CHEN, *Department of Information and Technology Education, Ministry of Education*
Ms Chia-Hua LIN, *PhD student, National Taichung University of Education*
National Taichung University of Education Research Team

REFERENCES

Araka, E., Maina, E., Gitonga, R., & Oboko, R. (2020). Research trends in measurement and intervention tools for self-regulated learning for e-learning environments—systematic review (2008–2018). *Research and Practice in Technology Enhanced Learning, 15*(6), 1-21. https://doi.org/10.1186/s41039-020-00129-5

Boekaerts, M. (1997). Self-regulated learning: A new concept embraced by researchers, policy makers, educators, teachers, and students. *Learning and Instruction, 72*, 161-186.

Boekaerts, M, & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology 54*(2), 199-231.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65*(3), 245-281.

Cleary T. J., Slemp J., & Pawlo, E. R. (2021). Linking student self-regulated learning profiles to achievement and engagement in mathematics. Psychology in Schools, 58, 443–457. https://doi.org/10.1002/pits.22456

Dede, C. (2010). Comparing frameworks for 21st century skills. In J. Bellanca & R. Brandt (Eds.), *21st century skills: Rethinking how students learn* (pp. 51-76). Bloomington, IN: Solution Tree Press.

Dignath, C., and Büttner, G. (2008). Components of fostering self-regulated learning among students. a meta-analysis on intervention studies at primary and secondary school level. Metacogn. Learn. 3, 231–264. doi: 10.1007/s11409- 008-9029-x

Efklides, A. (2011). Interactions of metacognition with motivation and affect in self-regulated learning: The MASRL model. *Educational Psychologist, 46*(1), 6-25.

Hadwin, A., & Järvelä, S. (2011). Introduction to a special issue on social aspects of self-regulated learning: Where social and self meet in the strategic regulation of learning. *Teachers College Record, 113*(2), 235-239.

Harks, B., Rakoczy, K., Hattie, ., Besser, M., & Klieme, E. (2014). The effects of feedback on achievement, interest and self0evaluation: The role of feedback's perceived usefulness. *Educational Psychology, 34*(3), 269-290.

Heirweg, H., De Smul, M., Merchie, E., Devos, G., & Van Keer, H. (2021): The long road from teacher professional development to student improvement: A school-wide professionalization on self-regulated learning in primary education. *Research Papers in Education*, DOI: 10.1080/02671522.2021.1905703.

Kistner, S., Rakoczy, K., Otto, B., Dignath-van Ewijk, C., Büttner, G., & Klieme, E. (2010). Promotion of self-regulated learning in classrooms: Investigating frequency, quality, and consequences for student performance. *Metacognition and Learning, 5*(2), 157–171. https://doi.org/10.1007/s11409-010-9055-3

Kizilcec, R. F., Pérez-Sanagustín, M., & Maldonado, J. J. (2017). Self-regulated learning strategies predict learner behavior and goal attainment in Massive Open Online Courses. *Computers in Education, 104*, 18–33. https://doi.org/10.1016/j.compedu.2016.10.001.

Kuo, B.-C., Chang, F., & Mok, M. M. C. (5 December 2020). Development and validation of Self-regulated Learning Integrated Questionnaire. National Taichung University of Education.

Kuo, B.-C., Lin, C.-H., Pai, K.-C., Shih, S.-C., & Liao, C.-H. (2019). Using Learning Analytics to Explore the Performance of Chinese Mathematical Intelligent Tutoring System. In R. A. Sottilare and J. Schwarz (Eds.). HCII 2019, *Lecture notes in computer science* (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)11597 *LNCS*, 432-443. https://doi.org/10.1007/978-3-030-22341-0_34

Oers, B. V. (2020). Zone of proximal development (Vygotsky, lev). In D. T. Cook (Ed.), *The SAGE encyclopedia of children and childhood studies*. Sage UK.

Labuhn, A. S., Zimmerman, B. J., & Hasselhorn, M. (2010). Enhancing students' self-regulation and mathematics performance: The influence of feedback and self-evaluation standards. *Metacognition and Learning, 5*(2), 173-194.

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology, 28*(422), 1-28. https://doi.org/10.3389/fpsyg.2017.00422

Panadero, E., Klug, J., & Järvelä, S. (2016). Third wave of measurement in the self-regulated learning field: when measurement and intervention come hand in hand. *Scandinavian Journal of Educational Research, 60*(6), 723-735. https://doi.org/10.1080/00313831.2015.1066436

Perry, N. E., & Winne, P. H. (2006). Learning from learning kits: gStudy traces of students' self-regulated engagements with computerized content. *Educational Psychology Review, 18*(3), 211-228.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 452–502). San Diego, CA: Academic Press

Proske, A., Narciss, S., & Körndle, H. (2011). Exploring the effects of an optional learning plan tool in technology-enhanced learning. In G. Dettori & D. Persico (Eds.), *Fostering self-regulated learning through ICT* (pp. 315–333). NY: Information Science Reference.

Schmitz, B., & Perels, F. (2011). Self-monitoring of self-regulation during math homework behaviour using standardized diaries. *Metacognition and Learning, 6*(3), 255–273. doi:10.1007/s11409-011-9076-6

Sitzmann, T., & Ely, K. (2011). A meta-analysis of self-regulated learning in work-related training and educational attainment: what we know and where we need to go. Psychological Bulletin, 137, 421–442. doi: 10.1037/a0022777

Ting, M. Y., & Kuo, B. C. (2016). A knowledge-structure-based adaptive dynamic assessment system for calculus learning. *Journal of Computer Assisted Learning, 32*(2), 105-119. https://doi.org/10.1111/jcal.12119

Winne, P. H., & Perry, N. E. (2000). Measuring self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 531–566). San Diego: Academic.

Wu, H.-M., Kuo, B.-C., & Wang, S.-C. (2017). Computerized dynamic adaptive tests with immediately individualized feedback for primary school mathematics learning. *Educational Technology and Society, 20*(1), 61–72.

Vygotsky, L.S. (1978) *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press.

Yang, S.-J., Kuo, B.-C., & Lin, C.-P. (2021). A study of knowledge structure-based computerized adaptive test system for elementary school students on the effectiveness of remedial math. *International Journal on Digital Learning Technology, 13*(1), 23-48.

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

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal*, *45*(1), 166–183. https://doi.org/ 10.3102/0002831207312909

Zheng, L. (2016), The effectiveness of self-regulated learning scaffolds on academic performance in computer-based learning environments: a meta-analysis. *Asia Pacific Education Review*, *17*, 187–202.