

# Learning Analytics in Ubiquitous Learning Environments: Self-Regulated Learning Perspective

Masanori YAMADA<sup>a\*</sup>, Fumiya OKUBO<sup>a</sup>, Misato OI<sup>a</sup>, Atsushi SHIMADA<sup>a</sup>,  
Kentaro KOJIMA<sup>a</sup> & Hiroaki OGATA<sup>a</sup>

<sup>a</sup>*Faculty of Arts and Science, Kyushu University, Japan*

\*mark@mark-lab.net

**Abstract:** This research aims to investigate the relationship between self-regulated learning awareness, learning behaviors, and learning performance in ubiquitous learning environments. In order to do so, psychometric data about self-regulated learning and log data such as marker, annotation, accessing device types that stored the learning management system were collected and analyzed using multiple regression analysis with stepwise method. The results indicated that self-efficacy, internal value, and the number of read slides had a significant influence on the final score, and the awareness of cognitive learning strategy use has slightly significant power to predict the final score.

**Keywords:** Learning Analytics, Self-Regulated Learning, Ubiquitous Learning

## 1. Introduction

As information and communication technology (ICT) advances, data collection is taking place through various methods, in particular, ubiquitous technologies (Yin et al., 2015). From the learner's perspective, ubiquitous technologies allow for learning to happen anytime and anywhere, and allow the collection of learning log data out of class hours. However, psychometric data such as learning style and motivation as well as learning logs should be collected, in order to analyze learners' behaviors for providing effective learning support. Awareness of Self-regulated learning (SRL), which is one of the most important perspectives in educational research, is found to be helpful. This paper aims to investigate the learning behavior and SRL factor(s) that influence learning performance, examining the relationship between learning behaviors, SRL factors, and learning performance.

## 2. Review of previous research

### 2.1 Self-regulated learning

In using ICT, learners can control when, what, and how they learn, without the restrictions of time, learning space, and printed materials (Cunningham and Billingsley, 2003). One of the most popular platforms worldwide, the Learning Management System (LMS) offers the opportunity to learn outside class using the Internet. To exercise control in online learning, learners have to develop self-regulated learning (SRL) skills (Yukselturk and Bulut, 2007). SRL is the active learning process used to regulate and monitor learning cognition, motivation, and behavior, and to set personal learning goals, including social aspects (Wolters, Pintrich and Karabenick, 2003; Schunk and Zimmerman, 2008). Goda et al. (2013) conducted research about the relationship between SRL and learning performance. Goda et al. (2013) suggested that one of the SRL skills is adaptive help seeking, which leads to better academic performance. They concluded that a sense of seeking help can be useful in predicting learners' academic performance.

SRL is also related to motivation, cognition, and self-control, as it is directed toward the accomplishment of learning purposes (Pintrich, 1999; Zimmerman, 1995). SR learners are those who can prepare a learning plan, adjust it, and apply self-control and self-evaluation (Deci, Ryan, and

Williams, 1996). Goda, Yamada, Kato, Matsuda, Saito, and Miyagawa (2015) suggested that high-level SR learners can control and manage their learning plan in the context of their everyday lives. SRL is closely linked to the concept of autonomy, particularly in the aspects of metacognition, motivation, and learning behavior (Schunk and Zimmerman, 1998; Zimmerman, 1986), which enables learners themselves to take responsibility for learning. SRL skills are essential for effective and continuous learning.

Wolters et al. (2003) organized SRL into four phases: forethought (planning and activation), monitoring, control, as well as reaction and self-reflection (see Table 1). Several studies have suggested that the second and third phases can happen simultaneously (Pintrich, Wolters, and Baxter, 2000). Schunk and Zimmerman (1998) developed a similar model for SRL, which comprises three phases: forethought, performance/volitional, and self-reflection (see Figure. 1).

Table 1: Differences between naïve and skillful SRLs (Schunk and Zimmerman, 1998)

Classes of self-regulated learners		
Self-regulatory phases	Naïve self-regulators	Skillful self-regulators
Forethought	Nonspecific, distal goals	Specific, hierarchical goals
	Performance goal orientation	Learning goal orientation
	Low self-efficacy	High self-efficacy
	Disinterested	Intrinsically interested
Performance/volitional control	Unfocused plan	Focused on performance
	Self-handicapping strategies	Self-instruction/imagery
	Outcome self-monitoring	Process self-monitoring
Self-reflection	Avoid self-evaluation	Seeking self-evaluation
	Ability attributions	Strategy/practice attributions
	Negative self-reactions	Positive self-reactions
	Nonadaptive	Adaptive

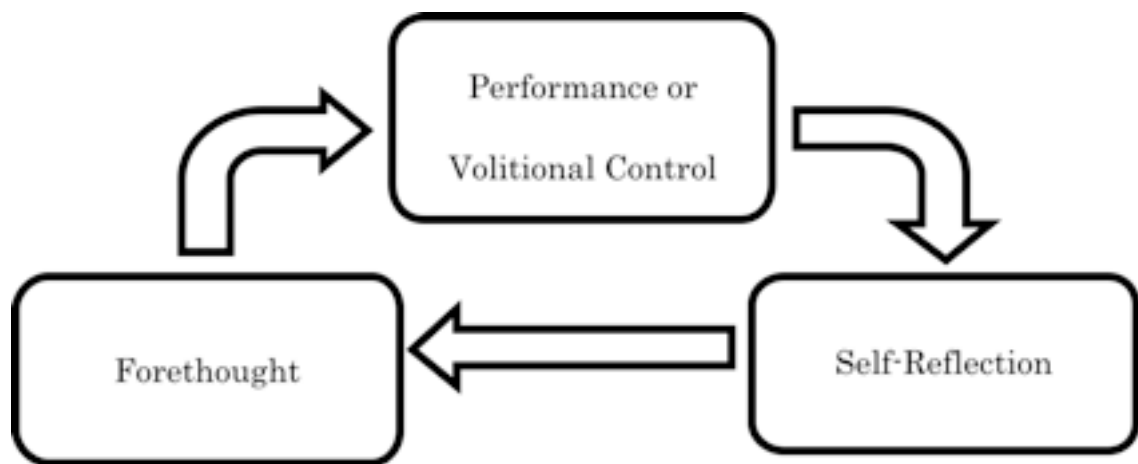


Figure 1. SRL cycle (Zimmerman, 1988)

Schunk and Zimmerman (1998) further compared the learning behaviors of novice and expert SRL learners in each SRL phase (see Table 1). In the forethought phase, skillful learners could articulate their final goals, as well as the necessary steps toward accomplishing the same. The features of both the goal and the steps toward it were constructive and clear. Skillful learners also tended to have internal motivation and high self-efficacy. In the performance/volitional phase, skillful learners enhanced their learning by monitoring the learning process. In the self-reflection phase, they sought to evaluate their learning performance independently and tended to attribute its quality to learning strategies and

practice. The SRL features of the skillful learners in each phase support learning processes by helping teachers predict learning styles and learning performance.

## *2.2 SRL in a computer-based learning environment*

Previous SRL research has focused mainly on the face-to-face classroom setting, but several scholars have also conducted studies on the computer-assisted learning environment (e.g., Azevedo, 2005). Recent research is focusing on SRL in an ICT-based learning environment, as ICTs are now used in education and learning settings. Attitudes towards the use of ICT affect SRL. Usta (2011) indicated that a negative attitude toward ICT use has a positive relationship with goal setting, time management, help-seeking, and self-regulation. Greene and Azevedo (2010) indicated that learners who do well in an ICT-based environment can manage their learning using cognitive and metacognitive processes, such as ensuring the effectiveness of learning strategies, setting learning objectives, and self-monitoring. Greene, Muis and Pieschl (2010) reviewed learning support in four types of ICT-based learning environments. One is behaviorism, such as drill and practice, in which the same questions are asked and answered repeatedly, followed by the reception of the same feedback. The second is an adaptive or intelligent tutoring system, which supports the activation of metacognition and information retrieval. The third is hypertext and hypermedia, which allow the organization of digital learning materials using linked information. Hypertext and hypermedia work as open-learning material databases. The last one is simulation, which supports cognitive and metacognitive learning, such as information organization, hypothesizing, observation, and learning output. As such, an ICT-based learning environment supports SRL skill acquisition by indirectly promoting the use of cognitive and metacognitive learning strategies.

## *2.3 Learning Analytics*

Learning analytics have been the subject of attention in educational research over the world, as the findings of learning analytics studies can be applied to improve education, create learning supports, establish learning models, and so on (Yin et al., 2015). One of the key issues in learning analytics is to collect learning logs using ICT. As ICT advances, the methods of data collection have been various, and in particular, the focus here is on ubiquitous technologies. Ubiquitous technology can enhance the awareness and behaviors about SRL, because ubiquitous technology allows learner to access learning materials anywhere and anytime. Yamada et al. (2011) developed mobile-based language learning environment for business people, in order to the business people to learning English listening skills in their commuting time. Sha et al. (2012) developed the mobile based learning program for elementary science classes from the perspective of SRL.

Oi et al. (2015) investigated the relationship between the learning performance and the frequency of link among pages in learning materials using logs. The results revealed that good-achievement learners tended to link the pages and knowledge with learning materials. Goda et al. (2015) identified seven distinct learning behavior types using learning logs, 1: procrastination, 2: learning habit, 3: random, 4: diminished drive, 5: early bird, 6: chevron, and 7: catch-up. They revealed that the students who had the learning habit type and chevron type gained better scores than the procrastination type.

One of the common issues under discussion is how psychological variables affect learning performance in a learning environment using ICT (Greene and Azevedo, 2010). Psychometric data as well as learning logs should be collected, in order to analyze learners' behaviors for effective learning support, and in particular, learning styles such as self-regulated learning (SRL) should be helpful (Roll and Winne, 2015). Yamada et al. (2015) indicated that self-efficacy, which is one of the factors of SRL, had significant correlation with learning behaviors such as highlighting and annotation. However, their limited research did not investigate the causal relationships between SRL and learning behaviors. If a relationship between self-regulated learning and learning behaviors is found, the results may be used to support learners effectively.

## 2.4 Research purpose

Reviewing the previous research, analysis about the relationship between SRL and learning behaviors needs to be conducted, in order to support teaching and learning. However, log types were limited, and the relationship between SRL awareness and learning behaviors was unclear. From the viewpoint of learning analytics, various log types for the analysis need to be considered for the support of teaching and learning. This research aims to investigate the relationship between SRL factors, learning behaviors, and learning performance, in particular, learning behaviors about cognitive learning strategies such as marker and annotation, accessing days, and accessing device type.

## 3. Method

### 3.1 Participants and Class

This research was conducted in an information technology course (15-week course). The participants were 93 freshman university students. The teacher distributed digital learning materials to the students with the use of digital learning material reader (DLMR) in ubiquitous learning environments, and encouraged the students to read the materials in advance, before the commencement of every class. DLMR allowed the students to access the learning materials on devices such as laptops, tablets, and smartphones, and to use marking and annotation functions, whenever and wherever Internet was available. In class, learners were engaged in programming practice, after the comprehension test in every class. Figure 2 shows the several interface capture of DLMR. The students were required to answer questionnaires before the first class (pre questionnaire) and at the end of the last class (post questionnaire).

### 3.2 Data Collection and Analysis

Two methods were used for the data collection: a questionnaire and log. The Motivated Strategies and Learning Questionnaire (MSLQ) (Pintrich and DeGroot, 1990), which consists of five factors (Self-Efficacy: SE, Internal Value: IV, Cognitive Strategies: CS, Self-Regulation: SR, Test Anxiety: TA; 44 items in sum, rated on a seven-point Likert scale from 1(negative) to 7(positive)), was used for the subjective evaluation of learners' SRL skills. Items in MSLQ were displayed in Appendix. A.

The students were asked to complete the MSLQ both before and after the classes. The differences between their responses on the pre and post questionnaires were analyzed. The second method of data collection was a log that recorded the number of slide pages that learners read, and their marking and annotation behaviors. The number of transactions from both laptops and portable devices, and the accessed days were also recorded. The final score is the learning performance.

## 4. Results

### 4.1 Descriptive data

The collected data indicates the number 90, as those who answered pre- and post MSLQ. Tables 2 and 3 show the descriptive data and the results of t-test of MSLQ (mean of sum-up score in each factor), learning behaviors (frequency in 15-week), and the final score. The results of paired t-test show the significant difference between pre- and post scores of MSLQ in SE.

In order to investigate the relationship between each SRL factor, learning behaviors, and final score, stepwise multiple regression analysis was conducted, setting the final score as dependent valuable, and the difference between pre- and post-scores of each MSLQ factor and learning behaviors as independent valuables. This point will be explained in the next section.

### 4.2 Multiple Regression Analysis

In order to investigate the effects of SRL factors and learning behaviors on learning performance, we conducted multiple regression analysis with stepwise methods. We set the final test score as dependent variable, and other factors and learning behaviors as independent variables. This analysis

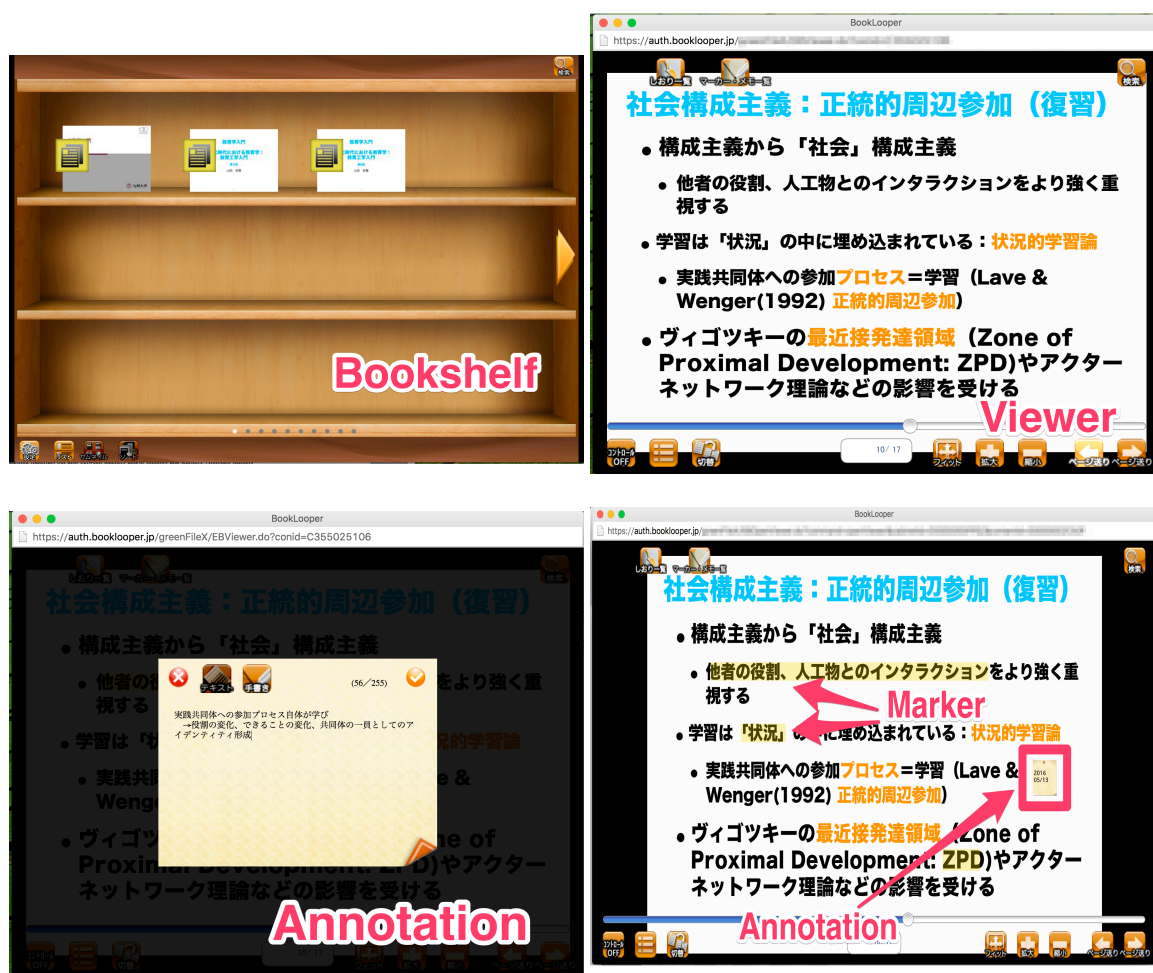


Figure 2. The Interface of Digital Learning Material Reader “BookLooper”

eliminated the variables more than 10% probability level. Table 4 revealed the results. The results showed that SE, IV, CS, and frequent reading of slides significantly affected the final score. SE, IV, and slides had positive effects on the enhancement of the learning performance, and CS has slight significance. However, IV had negative impact. Considering the  $R^2$ , significance, and Variance Inflation Factor (VIF), model fitness seems to be acceptable to some extent. However, three variables, i.e., IV, marker, and annotation should be considered, from the perspective of model application, due to the large standard deviation.

Table 2: Descriptive data and the results of t-test of MSLQ

Variables	Pre-Post	Mean	SD	Min.	Max.	t	P
SE	Pre	32.77	8.43	9	54	3.82	p = 0.000
	Post	36.63	10.01	12	63		
IV	Pre	45.08	6.22	29	58	0.99	n.s.
	Post	44.18	8.46	16	63		
CS	Pre	59.47	8.16	21	81	0.84	n.s.
	Post	60.20	8.94	38	90		
SR	Pre	35.90	5.66	15	46	0.99	n.s.
	Post	36.57	6.61	17	63		
TA	Pre	15.51	4.20	4	27	1.17	n.s.
	Post	16.08	4.23	6	24		

n.s.: non significant

Table 3: Descriptive data of learning behaviors and the final score

Variables	Mean	SD	Min.	Max.
Slide	1692.17	1362.00	0	5365
Marker	5.97	11.62	0	83
Annotation	4.23	9.72	0	62
Transaction by Laptop	2203.26	1819.69	0	6762
Transaction by Mobile	58.11	377.06	0	2677
Access Days	8.92	6.88	0	42
The final score	85.09	11.72	39.93	101.25

Table 4: The results of multiple regression analysis with stepwise methods

Variables	Coef.	SE	$\beta$	P
SE	0.432	0.153	0.320	p = 0.006
IV	-0.594	0.186	-0.389	p = 0.002
CS	0.276	0.164	0.174	p = 0.096
Slide	0.004	0.001	0.469	p = 0.000

Note:  $F(4, 83) = 10.99$ ,  $p < 0.001$ ,  $R^2 = 0.346$ , Adjusted  $R^2 = 0.315$  VIF: IV 1.93, SE 1.70, CS 1.40, Slides 1.01

## 5. Discussion

This research aims to investigate the causal relationship between each SRL factor, learning behaviors, and the final score, using multiple regression analysis. The result revealed that self-efficacy, internal value, and the reading of slide numbers had significant effects on the final score, and the awareness of the use of cognitive learning strategy had weak effects on it. Interestingly, the use of mobiles, which plays important roles in ubiquitous learning, did not contribute to the enhancement of the learning performance. This is because few learners used a mobile device in this class for the review of the learning materials. In fact, only four out of ninety learners used a mobile device in this class. Mobile use did not seem to be a powerful variable for the prediction of the final score, due to the limited number of mobile users.

Self-efficacy and cognitive learning strategy can contribute to the enhancement of learning behaviors (Yamada et al, 2015), and the improvement of learning performance (e.g., Chang et al., 2014). However, the internal value had a negative causal relationship with the final score. A possible reason for the same is that several students, who are not good at information technology, seemed to gain bad scores. This class was an obligatory one for the students taking the pre-service teacher course. The students recognized the importance and necessity of this class, but their major was not within the information technology department. Number of the slide enhances learning performance. Possible reason is that learners that read and learn much input information gained high score.

## 6. Conclusion and Future Works

This research investigated the relationship between SRL factors, learning behaviors, and learning performance. The results showed that three factors and one learning behavior have influence on the final score. As implementation, these results seem to contribute towards designing an effective instruction. This research recommends that teachers design the class for enhancing the learner's self-efficacy, using the awareness of cognitive learning strategies. For instance, to introduce useful cognitive learning strategies for one's class is a simple idea, but can be consist of an effective instructional design method. Further, this research found several problems that researchers can focus on, as part of future research. Five points that can be looked at in the future need to be indicated here.

Overall relationship among all variables also requires investigation, in order to understand the key points to support learners. Second, the effects of mobile usage should be investigated, to promote

the use of mobiles. In this study, only four out of ninety learners used mobiles, in order to read the slide. Mobile usage can make learners aware of learning anywhere and anytime. This feature seems to enhance the SRL awareness. Sha et al. (2012) pointed out the learner's academic achievement and motivation affect on the use of mobile-based learning environment from the viewpoint of SRL. We should consider their suggestion for further research. Third, duration of accessing days should be added as variables for the prediction of learning performance. Regular access can have influence on the SRL awareness, and can lead to an improvement in learning performance. Fourth, the relationships among the variables collected in this study should be analyzed, in order to investigate the SRL effects on learning behaviors and learning performance in detail. Lastly, data analysis can include the addition of data from other classes. This research used data from a single class, but we should analyze the data including data from other classes, in order to extract a useful and versatile model for teaching and learning support.

## Acknowledgements

The research is supported by “Research and Development on Fundamental and Utilization Technologies for Social Big Data” (178A03), the Commissioned Research of the National Institute of Information and Communications Technology (NICT), Japan; Grant-in-Aid for Scientific Research (S) No. 16H06304 and the Education Enhancement Program (EEP) of Kyushu University.

## References

- Azevedo, R. (2005). Using hypermedia as a metacognitive tool for enhancing student learning? The role of self-regulated learning. *Educational Psychologist*, 40(4), 199-209.
- Chang, C-S., Liu, Z-F., Sung, H-Y., Lin, C-H., Chen, N-S. & Cheng, S-S. (2014). Effects of online college student's internet self-efficacy on learning motivation and performance, *Innovations in Education and Teaching International*, 51(4), 366-377
- Cunningham, C. A. & Billingsley, M. (2003). *Curriculum Webs: A Practical Guide to Weaving the Web into Teaching and Learning*. Boston, MA: Pearson Educational, Inc.
- Deci, E. L., Ryan, R. M., & Williams, G. (1996). Need satisfaction and the self-regulation of learning. *Learning and Individual Differences*, 8, 165-183.
- Goda, Y., Yamada, M., Matsuda, T., Kato, H., Saito, Y. & Miyagawa, H. (2013). Effects of help seeking target types on completion rate and satisfaction in e-learning, *Proceedings of INTED 2013*, 1399-1403.
- Goda, Y., Yamada, M., Matsuda, T., Kato, H., Saito, Y. & Miyagawa, H. (2015). Procrastination and Other Learning Behavioral Types in e-Learning and Their Relationship with Learning Outcomes, *Learning and Individual Differences*, 37, 72-80, doi:10.1016/j.lindif.2014.11.001.
- Greene, J. A., Muis, K. R., & Pieschl, S. (2010). The role of epistemic beliefs in students' self-regulated learning with computer-based learning environments: Conceptual and methodological issues. *Educational Psychologist*, 45(4), 245-257.
- Greene, J. A. & Azevedo, R. (2010). The measurement of learners' self-regulated cognitive and metacognitive processes while using computer-based learning environments. *Educational Psychologist*, 45(4), 203-209
- Kramarski, B. & Gutman, M. (2006). How can self-regulated learning be supported in mathematical e-learning environments? *Journal of Computer Assisted Learning*, 22, 24-33.
- Oi, M., Yin, C-J., Okubo, F., Shimada, A., Kojima, K., Yamada, M. & Ogata, H. (2015). Analysis of Links among E-books in Undergraduates' E-Book Logs, *Proceedings of the 23rd International Conference on Computers in Education*, 665-669.
- Pintrich, R. R., & DeGroot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82, 33-40.
- Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research*, 31, 459-470.
- Pintrich, P. R., Wolters, C., & Baxter, G. (2000). Assessing metacognition and self-regulated learning. In G. Schraw (Ed.), *Metacognitive Assessment* (pp. 43-97). Lincoln, NE: The University of Nebraska Press.
- Roll, I. & Winne, P.H. (2015). Understanding, evaluating, and supporting self-regulated learning using learning analytics, *Journal of Learning Analytics*, 2(1), 7-12.
- Schunk, D. H. & Zimmerman, B. J. (1998). *Self-Regulated Learning: From Teaching to Self-Reflective Practice*. New York, NY: The Guilford Press.
- Schunk, D. H. & Zimmerman, B. J. (2008). *Motivation and Self-Regulated Learning: Theory, Research, and Applications*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Sha, L., Looi, C-K., Chen, W. & Zhang, B.H. (2012). Understanding mobile learning from the perspective of

- self-regulated learning, *Journal of Computer Assisted Learning*, 28, 366-378.
- Usta, E. (2011). The examination of online self-regulated learning skills in web-based learning environments in terms of different variables. *The Turkish Online Journal of Educational Technology*, 10(3), 276-286.
- Wolters, C. A., Pintrich, P. R., & Karabenick, S. A. (2003). Assessing academic self-regulated learning. Paper prepared for the Conference on Indicators of Positive Development: Definitions, Measures, and Prospective Validity. Sponsored by ChildTrends: National Institutes of Health.
- Yamada, M., Yin, C-J., Shimada, A., Kojima, K., Okubo, F. & Ogata, H. (2015). Preliminary Research on Self-Regulated Learning and Learning Logs in a Ubiquitous Learning Environment, *Proceedings of the 15th IEEE International Conference on Advanced Learning Technologies(ICALT 2015)*, 93-95
- Yamada, M., Kitamura, S., Shimada, N., Utashiro, T., Shigeta, K., Yamaguchi, E., Harrison, R, Yamauchi, Y. & Nakahara, J. (2011). Development and evaluation of English listening study materials for business people who use mobile devices: A case study, *CALICO Journal*, 29(1), 44-66.
- Yin, C-J., Okubo, F., Shimada, A., Kojima, K., Yamada, M., Fujimura, N. & Ogata, H. (2014). Smart phone based data collecting system for analyzing learning behaviors, *Proceedings of International Conference of Computers on Education 2014*, 575-577.
- Yukselturk, E. & Bulut, S. (2007). Predictors for student success in an online course. *Educational Technology and Society*, 10(2), 71-83.
- Zimmerman, B. J. (2008). Goal Settings: A key proactive source of academic self-regulation. In D. H. Schunk & B. J. Zimmerman (Eds.), *Motivation and Self-Regulated Learning: Theory, Research, and Applications* (pp. 267-295). New York, NY: Lawrence Erlbaum Associates.
- Zimmerman, B. J. (2008). Investigating Self-Regulation and Motivation: Historical Background, Methodological Developments, and Future Prospects, *American Educational Research Journal*, 45(1), 166-183.



**Appendix. A. Motivated Strategies and Learning Questionnaire (Pintrich and DeGroot, 1990)**

Factor	Item
Self-Efficacy	Compared with other students in this class, I expect to do well.
	I'm certain I can understand the ideas taught in this course.
	I expect to do very well in this class.
	Compared with others in this class, I think I'm a good student.
	I am sure I can do an excellent job on the problems and tasks assigned for this class.
	I think I will receive a good grade in this class.
	My study skills are excellent compared with those of other students in this class.
	Compared with other students in this class, I think I know a great deal about the subject.
	I know that I will be able to learn the material for this class.
Intrinsic Value	I prefer class work that is challenging so that I can learn new things.
	It is important for me to learn what is being taught in this class.
	I like what I am learning in this class.
	I think I will be able to use what I learn in this class in other classes.
	I often choose paper topics I will learn something from even if they require more work.
	Even when I do poorly on a test, I try to learn from my mistakes.
	I think that what I am learning in this class is useful for me to know.
	I think that what we are learning in this class is interesting.
	Understanding this subject is important to me.
Test Anxiety	I am so nervous during a test that I cannot remember facts I have learned.
	I have an uneasy, upset feeling when I take a test.
	I worry a great deal about tests.
	When I take a test, I think about how poorly I am doing.
Cognitive Strategy Use	When I study for a test, I try to put together the information from class and from the book.
	When I do homework, I try to remember what the teacher said in class so I can answer the questions correctly.
	It is hard for me to decide what the main ideas are in what I read. (R)
	When I study, I put important ideas into my own words.
	I always try to understand what the teacher is saying even if it doesn't make sense.
	When I study for a test, I try to remember as many facts as I can.
	When studying, I copy my notes to help me remember material.
	When I study for a test, I practice saying the important facts over and over to myself.
	I use what I have learned from old homework assignments and the textbook to do new assignments.
	When I am studying a topic, I try to make everything fit together.
	When I read material for this class, I say the words over and over to myself to help me remember.
	I outline the chapters in my book to help me study.
	When reading, I try to connect the things I am reading about with what I already know.
Self-Regulation	I ask myself questions to make sure I know the material I have been studying.
	When work is hard, I either give up or study only the easy parts. (R)
	I work on practice exercises and answer end of chapter questions even when I don't have to.
	Even when the study materials are dull and uninteresting, I keep working until I finish.
	Before I begin studying, I think about the things I will need to do to learn.
	I often find that I have been reading for class but don't know what it is all about. (R)
	I find that when the teacher is talking, I think of other things and don't really listen to what is being said. (R)
	When I'm reading, I stop once in a while and go over what I have read.
	I work hard to get a good grade even when I don't like a class.

Note: R means reversed items