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Recognizing and measuring self-regulated learning in a mobile learning environment

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ABSTRACT

With the realization that more research is needed to explore external factors (e.g., pedagogy, parental involvement in the context of K-12 learning) and internal factors (e.g., prior knowledge, motivation) underlying student-centered mobile learning, the present study conceptually and empirically explores how the theories and methodologies of self-regulated learning (SRL) can help us analyze and understand the processes of mobile learning. The empirical data collected from two elementary science classes in Singapore indicates that the analytical SRL model of mobile learning proposed in this study can illuminate the relationships between three aspects of mobile learning: students' self-reports of psychological processes, patterns of online learning behavior in the mobile learning environment (MLE), and learning achievement. Statistical analyses produce three main findings. First, student motivation in this case can account for whether and to what degree the students can actively engage in mobile learning activities metacognitively, motivationally, and behaviorally. Second, the effect of students' self-reported motivation on their learning achievement is mediated by their behavioral engagement in a pre-designed activity in the MLE. Third, students' perception of parental autonomy support is not only associated with their motivation in school learning, but also associated with their actual behaviors in self-regulating their learning.

1. Introduction

Mobile technologies forge ubiquitous learning spaces and experiences across different scenarios or contexts (Sharples, Taylor, & Vavoula, 2005, 2007). They have led us into a new phase in the evolution of technology-enhanced learning (TEL). Ubiquity, the most significant feature of wireless and mobile technologies, creates possibilities for learners to learn the right thing at the right time at the right place (Peng, Su, Chou, & Tsai, 2009). In their words, ubiquity "refers not to the idea of 'anytime, anywhere' but to 'widespread', 'just-in-time', and 'when-needed' computing power for learners" (p. 175). It is increasingly believed that this feature enables educators to facilitate and scaffold student-centered learning activities that encompass both formal and informal settings (Frohberg, Göth, & Schwabe, 2009; Looi et al., 2011; Zhang et al., 2010).

Although mobile learning is becoming popular in educational research and practices, there is under-theorization about the nature, process, and outcome of mobile learning (Sharples et al., 2005; Sharples et al., 2007; Wali, Winters, & Oliver, 2008). This is one of the main challenges facing mobile learning research. Many existing studies (Liaw, Hatala, & Huang, 2010; Wali et al., 2008; Waycott, Jones, & Scanlon, 2005; Zurita & Nussbaum, 2007) grounded and conceptualized the application of mobile technologies to learning in the framework of activity theory. Although those studies attached importance to the role of the learner in effective mobile learning, further research is still needed to unpack the roles of learner characteristics such as motivation in understanding and analyzing the mechanisms and processes of mobile learning. Specifically, more research is needed to explore external factors (e.g., pedagogy, parental involvement in the context of K-12 learning) and internal factors (e.g., prior knowledge, learning goals, and strategies) that underlie student-centered mobile learning. Student-centered learning logically assumes that students are the agents (masters) of their own learning in some manner. Mobile learning environments provide a means by which students can exercise agency to manage their own learning. This assumes that handheld computers can not only be used as cognitive tools (Chen, Tan, Looi, Zhang, & Seow, 2008), but also as metacognitive tools.

The intent of the present study is to exemplify how the theories and methodology of self-regulated learning (SRL), an active area in contemporary educational psychology (cf. Zimmerman & Schunk,

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2001a,b, 2011), can help to explicate and understand the mechanism and processes of mobile learning. Approaching this aim will lead to significant implications for addressing these challenges in the theorizing of mobile learning.

From a broader perspective, Azevedo (2005) explored how self-regulated learning can be used as a guiding theoretical framework to examine learning with advanced computer technologies that presumably include mobile technologies. According to Azevedo, our knowledge of the mechanisms underlying students' learning with technologies is lacking when compared with the technological advances which have made such technologies prevalent in homes, school, and at work. Thus, more research is needed to use multiple theoretical lens and multiple methods for better understanding the complex nature of learning with technology-advanced learning environments, in particular, mobile learning environments. These views are aligned with and support the current attempt to investigate mobile learning processes from the perspective of SRL.

In the following sections, the notion of self-regulated learning (SRL), its main components, and a phase model of SRL will be briefly reviewed. Based on this, an analytic SRL model of mobile learning for theoretically interpreting and analyzing mobile learning processes will be introduced. This model will be empirically substantiated by the measurement and statistical analyses of students' cognitive, metacognitive, and motivational processes in the context of a mobile learning intervention involving two elementary science classes in Singapore. Finally, the empirical findings, and theoretical and practical inferences for further research in both mobile learning and SRL will be interpreted and discussed.

2. Viewing mobile learning from the perspective of self-regulated learning

2.1. What is self-regulated learning?

Human behavior is conceived of as the product of an internal guidance system that inherently is organized; thus, the mechanism underlying human behavior is a system of self-regulation (Carver & Scheier, 1998). Self-regulation refers to a complex, super-ordinate set of functions located at the junction of several psychological areas including research on cognition, metacognition, problem solving, motivation, and so on (Boekaerts & Corno, 2005). The construct of self-regulated learning (SRL) is subsumed under a general concept of self-regulation (SR) (Boekaerts & Corno, 2005).

Scholars with different theoretical origins emphasize slightly different aspects of SRL from different perspectives (Agina, 2008; Zimmerman & Schunk, 2001a,b). Puustinen and Pulkkinen (2001) grouped Pintrich and Zimmerman's SRL theories and research together under social cognitive theory. The other influential SRL models include: Boekaerts' model of adaptable learning, Borkowski's process-oriented model of metacognition, and Winne's four-stage model of SRL. According to Puustinen and Pulkkinen, the definitions in the models of Boekaerts, Pintrich and Zimmerman characterize SRL as a goal-oriented process. Borkowski's and Winne's models view SRL as a metacognitively-governed process emphasizing the adaptive use of cognitive tactics and strategies to learning tasks. In the present study, the theoretical framework is built on the social cognitive theory of SRL. Meanwhile, Winne's model of SRL is applied to analyze the specific mobile learning processes in the project.

In Bandura's social cognitive theory (i.e., Reciprocal Determinism) (Bandura, 1986; Zimmerman & Schunk, 2001a,b), personal cognition (e.g., motivation, affect) is reciprocally determined by behavioral (e.g., opening a webpage) and environmental (e.g., teacher's feedback, parental support) factors. Humans are viewed as proactive, self-organizing, self-regulating rather than reactive organisms solely either shaped by external environmental influences or reflexively stimulated by genetic inner impulses (Bandura, 2001; Martin, 2004). In this theory, people are both products and producers of the environment in which their cognitive and behavioral functioning is determined. This implies that the effectiveness of any learning environment on learners' behavioral engagement in learning is mediated by learner characteristics such as prior knowledge, goals, and self-perception of the task. Thus, designing a mobile learning environment is not only concerned with technological issues, but with learners' personal factors and behavioral patterns.

Self-regulating learners are assumed to actively participate in their learning processes metacognitively as well as motivationally and behaviorally (Zimmerman & Schunk, 2001a,b). Various SRL theories share three basic assumptions (Zimmerman & Schunk, 2001a,b) that self-regulated learners are able to: (a) personally improve their ability to learn through selective use of metacognitive and motivational strategies; (b) proactively select, organize, and even create advantageous learning environments; and (c) play a significant role in choosing the form and amount of instruction they need. These assumptions about the nature of SRL essentially converge at a fundamental meta-theoretical element intrinsic in all SRL models – the construct of agency.

2.2. Human agency – theoretical foundation of SRL

Human agency refers to an emergent capability of individual humans to make choices (i.e. setting goals) and to act on these choices constituted primarily through interaction between brain activities and sociocultural contexts (Bandura, 2001; Martin, 2004). Agency is both determined by and determines the environment, and is philosophically connected to Piagetian constructivism, Vygotskian socioculturalism, and determinism (Martin, 2004). Agency has four main features: *intentionality*, *forethought*, *self-reactiveness*, and *self-reflectiveness* (Bandura, 2001).

In Bandura's theory (2001), intentionality represents the power to originate actions for a given purpose. This implies that although mobile devices make it possible for students to access mobile learning systems and engage in learning activities occurring in it, they do not do so without purpose. Forethought suggests that human behavior is motivated and directed by anticipated goals and outcomes, as well as planning. In this sense, self-regulated mobile learning stems from goal-directed behaviors. Self-reactiveness suggests an agent "has to be not only a planner and forethinker, but a motivator and self-regulator as well" (Bandura, 2001, p. 8). Finally, self-reflectiveness entails agents possess the metacognitive capability to reflect upon oneself, because "People are not only agents of action but self-examiners of their functioning" (Bandura, 2001, p. 10). Agency elicits two key components of SRL: *motivation* and *metacognition*.

2.3. Two key components of SRL – motivation and metacognition

Metacognition refers to the study of what people know about their cognitive and memory processes, and how they put the metacognitive knowledge to use in regulating their information processing and behavior (Koriat, 2007). Metacognition is referred to as cognition of cognition, knowledge about one's cognitive process, as well as skills of regulation of cognition (Nelson, 1999).

Researchers with different theoretical traditions tend to choose slightly different definitions or emphasize different aspects of the concept of motivation. From a cognitive perspective, Schunk, Pintich, and Meece offer a general definition of motivation: "Motivation is the process whereby goal-directed activity is instigated and sustained." (2008; p. 4)

According to Schunk et al. (2008), first, motivation refers to a mental process, thus, cannot be observed directly but rather must be inferred from its products – behaviors such as choice of task, effort, and so on. In this sense, motivation is internal and inferential in nature. Second, motivation is inherently related to goals that provide impetus for action. Thus, goal setting is indicative of motivation. Third, motivation can be expressed as either physical or mental activities. Physical activities involve effort, persistence, engagement, and so on. Mental activities entail cognitive operations such as encoding, retrieving, and solving problems. The former is observable and the latter is unobservable and inferential. Finally, motivation leads to the initiating and sustaining of activities.

Therefore, motivation impacts learning at least in two aspects: behavioral engagement and cognitive engagement (Linnenbrink & Pintrich, 2003). Behavioral engagement corresponds to the notion of physical, ''hands on'' activities (Schunk et al., 2008). For instance, research has found that students with high self-efficacy beliefs are not only more willing to spend more effort in the face of difficulty and to persist at tasks, but more likely to seek adaptive and instrumental help in the classroom. As a motivational construct in social cognitive theory, self-efficacy refers to a belief about one's capability to accomplish a specific task (Bandura, 1986). Cognitive engagement involves ''mind on'' actions in cognitive (mental) processes (Linnenbrink & Pintrich, 2003).

In self-determination theory (SDT) of motivation (Ryan & Deci, 2000), autonomy is viewed as a basic innate psychological motive of human beings. The need for autonomy refers to a sense of control over one's behavior. Intrinsically motivated people engage in an activity because they find it innately interesting and enjoyable. In contrast, extrinsic motivation leads people to engage in an activity as a means to attain some separate outcome such as a reward or avoidance of punishment. Intrinsic motivation corresponds to the proactive, growth-oriented nature of human beings (Ryan & Deci, 2000). Thus, the variance of student performance and achievement in mobile learning can be accounted for by the degree to which individual students are motivated intrinsically to ubiquitously engage in mobile learning activities.

Autonomy as an innate endorsement of one's action is one's subjective perception of or a sense of actions deriving from oneself – a feeling of choices over their own actions and thoughts. In classrooms, teachers cannot directly give students an experience of autonomy, but rather provide autonomy supports – a set of interpersonal behaviors to foster students' intrinsic motivation (Reeve, Ryan, Deci, & Jang, 2008). Since mobile technologies make it possible to bridge students' learning activities in both formal (e.g., in schools) and informal settings (e.g., in homes), autonomy-supports that nurture intrinsic motivation should be extended from classrooms to individual students' homes. Thus, the present study hypothesizes that the autonomy supports from students' parents play a role in influencing intrinsic motivation.

In developmental and educational psychology, parental autonomy support is viewed as the extent to which parents value and use techniques that facilitate independent problem solving, choice, and self-determination in their children (Soenens et al., 2007). There are two major sources of autonomy support underlying students' intrinsic motivation and self-regulation of learning when they are involved in a mobile learning environment: classroom teachers and parents. These will be elaborated by introducing the SRL model of mobile learning proposed below in the present study.

2.4. A proposed analytical SRL model of mobile devices as cognitive, metacognitive, and motivational tools

The present study proposes an analytic SRL model (see Fig. 1) for designing and analyzing mobile learning. At the center of the model is the notion of learner self-regulation as agency, which functions as internal driving forces initiating and sustaining a self-regulated mobile learning process. The key personal factors

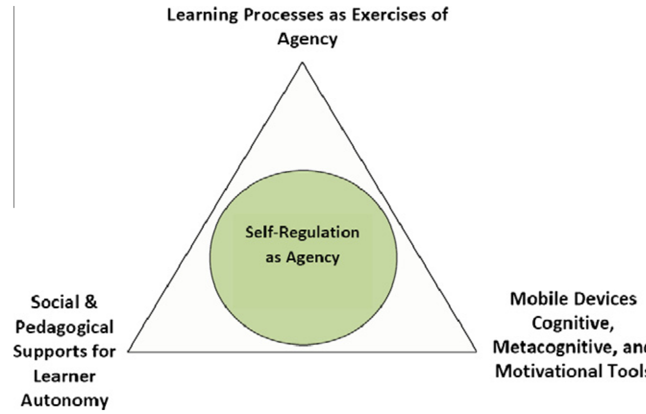

Fig. 1. An analytic SRL model of mobile learning.

with regard to agency include domain knowledge, prior experiences, motivation, and metacognitive awareness, epistemological beliefs, and so on.

Besides the notion of agency, this model comprises three dimensions. In light of SRL, first, mobile learning processes can be regarded as manifestation/exercises of agency (fundamentally composed of cognition, metacognition and motivation). Second, mobile devices are assumed to not only function as cognitive tools, but motivational and metacognitive tools. This hypothesis will be justified by applying Winne's phase model of SRL Winne (2001), Winne (2011) to analyzing the mobile learning system designed and used in the project. Third, in order to foster SRL, the mobile learning environment should offer some degree of freedom (i.e., learner autonomy) in a SRL processes such as setting goals, monitoring and controlling learning processes (e.g., selecting tasks, strategies, and study time), assessing and evaluating learning activities. To bridge learning across settings (e.g., classrooms and families), learner autonomy supports mainly come from two aspects: the teacher and the parents.

The present study treats the teacher's autonomy support as a pedagogical condition under which the students exercise agency in regulating their own learning. Research shows that autonomy-supportive teaching cultivates student SRL by promoting intrinsic motivation and learning performance, as well as skills in time management and concentration (Reeve et al., 2008). Self-determination theory (SDT) believes that autonomy support satisfies student innate need for autonomy and cultivates intrinsic motivation accordingly (Reeve et al., 2008).

The construct of parental autonomy support (PAS) in the present study was measured as an independent variable that presumably can account for the students' thoughts and actions of SRL. Empirical research has revealed that the influence of parents' involvement on student academic achievement is mediated by student motivation and self-regulation (Fulton & Turner, 2008; Wong, 2008; Xu, Kushner Benson, Mudrey-Camino, & Steiner, 2010). The instrument used in the present study will be introduced in the method section.

The discussion in the next sections will qualitatively and quantitatively substantiates this analytic SRL model of mobile learning. First, Winne's phase model of SRL (2001, 2011) will be used to conceptually illustrate how a mobile learning process can be understood and analyzed within the framework of SRL. Then, based on the conceptual analysis, specific research questions will be put forth and addressed through the empirical measurements and statistical analysis of the quantitative data obtained from a 5-week mobilized science teaching and learning in two Singaporean elementary classes.

3. Understanding a mobile learning process in Winne's SRL phase model

3.1. Background of the present study

In the three-year project, a Primary (Grade) 3 and 4 science curriculum was transformed for delivery by means of mobile technologies, and a teacher enacted the lessons over the 2009 and 2010 academic year in a primary class in Singapore. This class of students had a total of more than 40 weeks of the mobilized lessons in science, which were co-designed by teachers and researchers. Another class of students taught by another science teacher participated in the research in the 2010 academic year. They had about 20 weeks of using the mobilized science lessons.

In the pedagogical approach enabled by the harnessing of mobile technologies, the existing science curriculum for a grade level is transformed into a "mobilized curriculum" (Norris & Soloway, 2008). This is a transformation from a more content-centered and teacher-centered infrastructure to a systematic student-centered infrastructure that seeks to foster self-directed learning (Looi et al., 2011).

The mobile device chosen was the smartphone computer HTC TyTn II (Taoyuan, Taiwan, R.O.C.) which runs the Microsoft Windows Mobile 6 operating system. The software on the HTC Smartphone includes a calculator, a calendar, mobile web Internet access, MS Windows Mobile Word, Excel, and PowerPoint, which provide the affordances of basic math computation, self-monitoring, online search, digital production, data collection, data storage and analysis, and presentation. The GoKnow™ MLE (Mobile Learning Environment) is selected that supports our pedagogical philosophy and serves a malleable environment to support the mobilized curriculum.

The suite of applications on GoKnow includes Sketchy for drawing animation, iKWL (i.e., What do I know? What do I wonder? And What did I learn?) for creating KWL tables, PicoMap for concept maps and MyProjects to organized the mobile learning activities into lesson packages. Using the GoKnow's MyProjects, teachers design lesson packages that are downloadable to the students' mobile devices. Each lesson package contains a set of instructional activities, which may utilize one of mobile applications in MLE such as iKWL, Sketchy or PicoMap, to learn a science topic such as Interactions through Magnets or the Human Digestion System.

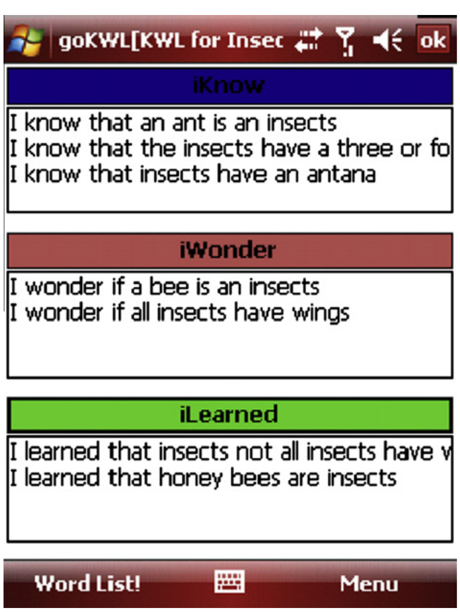

Fig. 2. An example of KWL in GoKnow™.

For each lesson package, the teachers designed a KWL table for students to fill in at the beginning of each lesson. The KWL table contains three pre-designed questions (Fig. 2): *What do I know (K)*? *What do I wonder (W)*? And *What did I learn (L)*? The first question is aimed at activating their prior knowledge and to elicit their understanding of the topic to be learned. By asking the question – "What do I wonder?" the students were encouraged to inquire into the topic by formulating their own questions driven by their own interests. Initiating the use of the KWL table early in the lesson allows teachers to understand the students' prior concepts of the subject and to encourage students to initiate their own inquiry of the subject over the duration of the lesson. The students were expected to answer the section on "What I did learn" only at the end of the lesson package in order to reflect on and summarize what they have learned.

In this sense, the KWL table built in the MLE encapsulates both metacognitive and motivational tools built in the mobile learning system in the present study. Answering any or all of the three questions in the KWL table invites the students motivationally and metacognitively to engage in mobile learning activities. This proposition will be elaborated by introducing and incorporating a phase model of SRL into the process of using the KWL tool built in the mobile learning system.

3.2. Winne's phase model of SRL – an approach to understanding the role of the KWL as a motivational and metacognitive tool

Winne's phase model of SRL postulates that SRL unfolds over four weakly sequenced and recursive phases (Winne, 2001; Winne, 2011): *defining the task*, *setting learning goals and plans*, *enacting*, and *adapting*. In his theory, the first three phases are necessary and the fourth phase is optional depending on whether the entire approach to work is to be evaluated at the end of a task. The following analysis will be focused on how the KWL questions built in the smart phone scaffold the students to go through the three necessary phases (Fig. 3). In the figure, the recursive feature of this model is denoted by the dotted arrows, indicating the possible impacts of psychological states at any subsequent phases on that at any previous phases. For example, a learner may make some adjustments to the learning goals he or she sets in Phase Two, or may reconstruct his/her perception of the task he or she generated in Phase One once he or she actually engages with learning cognitively and metacognitively in Phase Two.

In the project, the mobile lessons usually began with a collaborative (e.g., cooperative game) or individual activity (e.g., browsing the instructional objectives presented on the smart-phone) by which the students would get some initial knowledge about the background and topic of the lesson, as well as a few challenging questions addressing the key concepts (e.g., magnet) to learn. This corresponds to Phase One in a SRL process. By answering the first question in the KWL table (What do I already know about the topic?), in light of Winne's model (2001), Winne's model (2011), at least two types of knowledge and experiences stored in the long-term memory would be more or less activated: (a) some prior domain knowledge of the task; and (b) strategies used with similar tasks in the past.

Metacognitive monitoring and metacognitive control are the pivots on which a SRL turns (Winne, 2001), implying metacognitive operations is presumably ubiquitous throughout a process of SRL. In Phase One of SRL, by answering the first KWL question and the teacher's triggering questions, the students were actually metacognitively monitoring if and to what degree they have understood the lesson. In this phase, the first KWL ("What do I know?") question presumably yields two cognitive products: activated prior knowledge and strategies used before, and personal definition of task (i.e., individuals' perceived profile of task). The

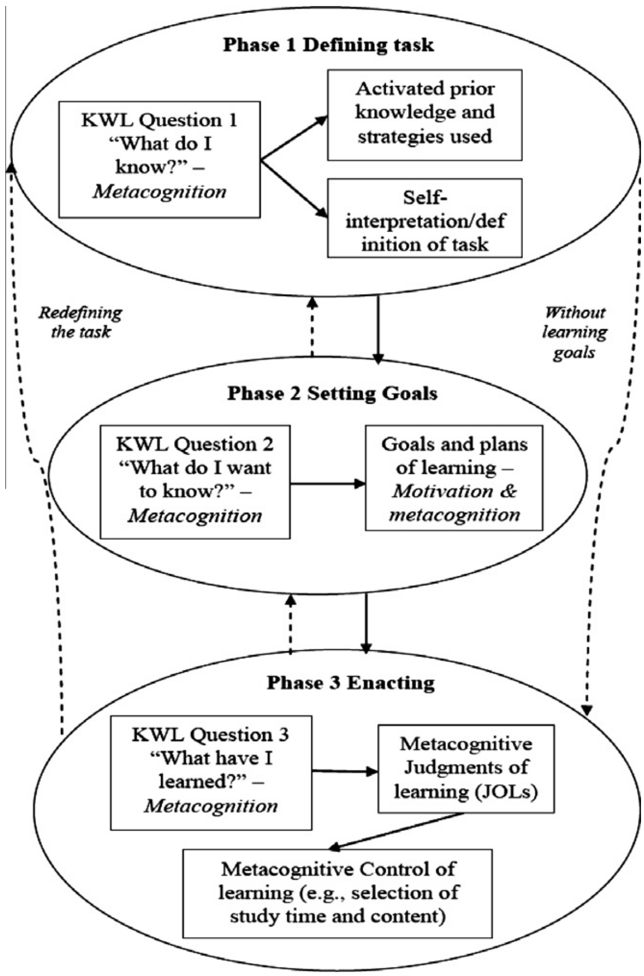

Fig. 3. Roles of KWL in the three necessary phases of Winne's model of SRL (2001).

variance in task definition may be attributable to the differences of personal factors (e.g., prior knowledge) between individual students. The external task conditions generated should be identical for each individual student. This suggests that the variability of learner characteristics manifested in Phase 1 of SRL (defining task) presumably sets a base for accounting for the individual differences in learning performance and achievement in the subsequent phases of mobile learning.

Having self-generated perceptions of the task in Phase One, self-regulating learners in Phase Two are supposed to set their own learning goals. The second KWL question is "What do I want to know". The KWL table here functions as a motivational tool by which students externalize their learning goals they set for themselves based on their understanding of the task (definition of the task), the product of cognitive operations in Phase One. Goals set by the students often are linked to but not necessarily identical to instructional objectives presented by the teacher when they act as agents to self-regulate their own learning (Winne & Nesbit, 2010). One of the basic assumptions of SRL is that learners play a proactive role in choosing the form and amount of instruction they need (Zimmerman, 2001). This implies that effective mobile learning environment should offer students some choices (i.e., learner autonomy) in self-directing their learning including setting learning goals.

Once goals are set, learners need to activate tactics or strategies stored in their long-term memory and work on the task in Phase Three (Winne, 2001; Winne, 2011). A crucial cognitive operation in Phase Three is monitoring the process of engagement by comparing the current state of learning with the goals set in Phase Two. In this phase, goals serve as standards for the students to metacognitively monitor the progress of learning. The KWL questions built in the mobile learning system scaffolds the students to monitor the current state of their cognitive process by asking themselves the question – "what have I learned". Comparing the answer to this question with the goals they set can yield their subjective judgment of learning (JOL) (e.g., how well have I learned? Have I reached my goals yet?), functioning as an internal feedback about the amount and rate of progress towards goals (Butler & Winne, 1995). This internal feedback regarded as an inherent mechanism for all self-regulated activities plays a vital role in guiding how the students complete a task by metacognitive controlling their behaviors, cognition, and motivation (Butler & Winne, 1995; Winne, 2001). Obviously, in this phase, the mobile devices equipped with KWL are presumably used as metacognitive tools.

4. Empirical measurements and analyses of SRL in mobile learning

4.1. Specific research questions

The above conceptual analyses essentially bring about a significant hypothesis – working with the KWL questions plays a specific role in fostering and analyzing students' SRL in the mobile learning environment. However, a central issue has not been solved yet: are there any empirical evidences validating this hypothesis? This fundamental issue can be unpacked to several specific questions or relies on other empirical measures on students' cognition, metacognition, and motivation. For example, people may ask what the relations are between applying the KWL tool and other contextual and personal factors in terms of SRL. The question is what the relevant quantitative measures should be included in this case for empirically evidencing this central hypothesis. This question can be addressed from two aspects.

First, SRL can be measured as an aptitude and/or an event (process) – dual character of SRL (Winne, 2001). SRL as aptitude suggests there is a relatively enduring personal trait that can be used to predict one's future performance. Aptitude measures of self-regulation are designed to aggregate self-regulatory responses over time and circumstances (Perry & Winne, 2006; Zimmerman, 2008) that are usually measured using self-report questionnaires. In contrast, an event is considered like a snapshot that essentially represents a sampling point in a larger time-domain process of development (Winne, 2001).

In the present study, since working on the KWL table under a condition of SRL involves students' on-the-fly actions in metacognition and motivation (two key components of SRL), students' answering the KWL questions can be treated as a SRL event occurring in the MLE. Students' motivation and metacognition as aptitudes were measured by a SRL survey that we developed. This SRL survey consists of four subscales measuring four elements of SRL: *self-efficacy beliefs*, *intrinsic motivation*, *extrinsic motivation*, and *regulation of learning*. The first three sub-scales correspond to the motivation components of SRL; the fourth subscale corresponds to a metacognition component of SRL. The details of the survey will be presented in the subsequent section. Therefore, it is natural to ask what the relation is between the self-reported SRL and online SRL behaviors (i.e., answering the KWL questions) occurring in the context of mobile learning.

Second, considering the predictive validity of any measurement, it is necessary to examine if and how either self-reported SRL (motivation and metacognition) or online behavioral measures on SRL can predict learning achievement – the third type of measures in the present study.

When student perception of parental autonomy support is taken into account, three specific research questions emerge. Answering the following questions will quantitatively provide empirical evidences supporting our analytic SRL model of mobile learning (shown in Fig. 2).

1. What are the relations between self-reported SRL in mobile learning and their perceived parental autonomy support for mobile learning?
2. How are students' self-reported SRL and perceived parental autonomy support for mobile learning associated with their engagement in answering the KWL questions?
3. How are students' self-reported SRL and parental autonomy support alongside their engagement in answering the KWL questions associated with their achievements in learning?

4.2. Participants

As of the end of July 2010, the two classes of students spent 5 weeks studying a scientific concept – magnet in the school. After data screening, there are 67 students as valid subjects in total (38 males and 29 females; 36 in Class A and 31 in Class B). The mobilized curriculum was introduced to Class B in January 2009, and to class A in January 2010. Thus, the students in Class B had a longer exposure history than that Class A to the mobile learning environment. In the evaluation system in Singaporean elementary education, Class A is ranked a higher position than Class B in terms of student academic achievement in the required courses including Science.

4.3. Procedure

Class A was a Primary 4 high ability class taught by a first-year Science teacher in 2010. The students of Class A were in the top quartile of the cohort. The teacher of this high ability class felt the need to teach her class well and prepare the students well for the school examinations. In her teaching, she emphasized the use of keywords and reinforced concepts that would prepare her students to answer questions in examinations. At the beginning of the series of lessons on magnets in early August 2010, she was observed to teach the class through direct instruction and Initial-Response-Evaluate (IRE) patterns. At the end of the series of lessons in which there was more group work and students were given opportunity to interact with magnetic materials, the teacher adopted a facilitator role as she engaged the children in discussion and asking inquiry-based questions.

Class B was taught by a teacher who was in her fourth year of teaching. She was involved in the co-design and enactment of the mobilized lessons ever since the present research began in 2009. We observed a marked change in her teaching practices with the enactment of the mobilized lessons. Before the introduction of the Smartphone, she relied heavily upon the textbooks and worksheets given in the class. Answers were given out to the students to fill in the worksheets as they needed to be taught how to answer correctly. Using the mobilized Science curriculum and the Smartphone in the classroom, the teacher enacted the curriculum to solicit student participation and construct their own understanding of the subject matter. She encouraged the students to look for the answers by using their Smartphone when they have questions. She adopted a facilitator role from the beginning of the series of lessons on magnets. During the lessons, she discussed with the students about the activities and write questions raised by the students during the discussion on the whiteboard. She encouraged the students to write those questions in the KWL table and find out the answers on their own, but did not require the students to fill in the KWL table in their mobile devices. In other words, each student had a choice in controlling their motivational and metacognitive behaviors by setting their goals of learning and monitoring the state of learning. In this sense, they were conditioned in a self-regulated mobile learning.

4.4. Measurements

The quantitative measurement in the present study can be grouped into three categories: self-report surveys, online behavioral data, and learning outcome. First, in the second week of the 5-week lessons on the concept of magnet, a 5-point Likert scale survey was administered in the two classes. It measures three motivational variables (i.e., self-efficacy (SE), intrinsic motivation (IM), and extrinsic motivation (EM)) and one metacognitive awareness variable (e.g., strategic regulation of learning). This SRL instrument is developed on the basis of the MSLQ (Duncan & McKeachie, 2005; Pintrich, Smith, Garcia, & McKeachie, 1993). Each subscale has six items (see Appendix A). All the items in this survey questionnaire are directly defined in the context of learning a specific scientific concept – magnet. For example, a self-efficacy item is "I believe I am able to learn well the concept of magnet"; an intrinsic motivation item is "Even when completing the assignments does not guarantee that I get a good grade, I still love to complete them".

The 5-point Likert scale SRL survey used in the present study is a product of transforming the widely used instrument for measuring motivation and metacognition – Motivated Strategies for Learning Questionnaire (MSLQ; Duncan & McKeachie, 2005; Pintrich et al., 1993) into a scale that can be appropriately applied in the context of Singaporean elementary science classes.

The students were required to select an answer from the five options: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree, which were coded as 1, 2, 3, 4, and 5 respectively in the data analysis. Thus the higher score on a variable a student reported, the lower value he or she had on that variable. For instance, if the mean score student A obtained for intrinsic motivation is 2, and the mean score student B obtained is 3.5, that would mean that student A reported a higher intrinsic motivation than student B. As a sub-study of the three-year research project, this scale is aligned with the coding scheme used in the entire project.

Second, another 5-point Likert scale survey was conducted after the 5-week experiment (in November 2010) to measure students' perception of a degree of autonomy support they obtained from their parents when they interacted with them in using the mobile device to learning science out of school. This is the parental autonomy support (PAS) survey. The PAS survey consists of seven items (see Appendix B). Based on self-determination theory (SDT) it refers to the extent to which parents value and facilitate independent problem solving, choice, and self-determination in their children (Soenens et al., 2007). The same coding scheme used for the motivational variables was adopted to measure PAS, that is, the higher PAS scores mean the weaker perceived PAS.

Two variables were used to measure students' online behavioral engagement in answering the KWL questions: KWL_p and KWL_s. First, KWL_p as a categorical variable measures whether or not individual students did fill in the pre-designed KWL table in which1 denotes the action of answering the KWL questions, 0 denotes no action of answering the KWL questions. In our code scheme, '1' was offered to anyone as long as he or she answered any one of the three KWL questions regardless of the quality of the answer. Second, a scoring rubric (see Appendix A) was developed and used to further measure the degree to which each student finished the KWL artifact, denoted as KWL_s variable.

Students' answers to each of the KWL questions may contain more than one item. Each item is given one point. Since the differences between the three questions (categories) in the KWL table are conceptually significant in terms of the phase model of SRL, one point of weight is granted to each category, namely, categorical weight. For instance, the first KWL question – "What do I know?" functions as a metacognitive tool (activator) to bring some prior knowledge relevant to the learning task to one's working memory, generating learner's own interpretation/definition of the task. Its role is different the second KWL – "What do I wonder?" in guiding a SRL process. The latter scaffolds the students in setting their own goals of learning. Thus, it is believed to be reasonable to add one-point categorical weight to the whole score of KWL. The rubric contains:

- 1 point for each item.
- 1 point for each category (I know, I wonder, I learned). The highest score of category is 3. The lowest is 1.
- The total score is the sum of the points for items and the category score.

For example, student A wrote one item under each of the three categories, the category score she got is 3, so her total score is 3 + 3 = 6. If student B wrote three items under a category, her category score is 1, so the total score is 3 + 1 = 4. The disparity of score between them is due to the variance in the degree to which they metacognitively engaged in the mobile learning environment by means of filling in KWL table. Although student B had three items, he or she actually engaged in one category of metacognitive activities (e.g., monitoring the state of learning), while, student A having three items completed three actions in metacognition and motivation (i.e., activating prior knowledge and defining the task; setting goals; and monitoring the state of learning). This qualitative difference between the two students in their performance in KWL may not be recognized without the addition of the categorical weight (see Table 1). Of course, it is realized there must be many alternative approaches to quantify this individual difference in using KWL.

Finally, each student's scores on three test questions on the magnet were extracted from the final examination which was conducted in November 2010 as the measure on their achievement in learning this concept. The full score for each question is 3.

4.5. Data analysis and results

The internal consistency reliability (Cronbach's Alpha) of each survey scale exceeds .7 (see Table 2). Among the 67 valid subjects, 36 came from Class A, and 31 came from Class B. 32 of the 67 valid subjects at least answered one KWL question, and 35 of them did not engage in it at all during the selected 5-week lessons. The number of students who answered the KWL questions in Class B is larger than that in Class A. The former had a longer history of engaging in the mobile learning environment. But, a Chi-Square test the gap between the two classes is not statistically detectable in KWL ($p > .05$). Also, no statistically detectable difference between the male and female was found in working on the KWL ($p > .05$).

First, outliers were controlled. To detect the univariate outliers, the z-scores of the values of all measured variables were computed. Cases with absolute z-scores > 3.08 ($p < .001$) were declared univariate outliers. To preserve data, actual outlying values were replaced with trimmed scores equal to one raw scale unit greater than the highest score falling below the criterion z-value of 3.08 (Tabachnick & Fidell, 2007).

A summary of statistical analysis on each of the four subscales on students' motivation and metacognition is presented in Table 2, displaying the means and standard deviations, α (internal consistency reliability), as well as the values of Skewness and Kurtosis. Kolmogorov–Smirnov (K–S) test was used to examine if these variables are distributed normally. Table 2 shows all the p-values in the K–S tests exceed the threshold (.05), indicating that the

Table 1
Examples of students' KWL notes.

An example of high scored KWL	An example of low scored KWL
I Know	*I Know*
Magnets attract magnetic materials like iron and steel. Unlike poles attract/like poles repel m magnet and a magnetic object attract a temporary magnet and a magnetic object will attract	*I Wonder* Why are magnets important
I Wonder	*I Learned* Magnets are important because it help us to make things easily
What is the difference that you observe between the fishing rod and the button magnet. Is stainless steel magnetic? Coloured drawing board>Why does the colour iron filling will not jumbled together? Is titanium magnetic	
I Learned Magnet are usually in places that you don't think about stainless steel are not magnetic	

Table 2
Statistics for each measured variable.

	N	Mean	SD	α	Skewness	Kurtosis	p (K–S)
Self-report surveys[a]							
Self-efficacy belief (SE)	67	2.06	.69	.80	.48	.14	.09
Intrinsic motivation (IG)	67	1.90	.67	.74	.49	−.56	.07
Extrinsic motivation (EG)	67	2.08	.91	.72	.67	−.08	.10
Regulation of learning (RL)	67	2.20	.85	.72	.98	1.11	.06
Parental autonomy support	54	2.37	.77	.78	.80	.33	.53
Achievement[a]							
Magnetism	54	5.18	1.01		−.59	.08	.11
Process artifacts[b]							
KWL_score	32	8.36	4.67		.65	−.20	.21

[a] 5-Point Likert scales. Lower figures correspond to higher values of the measures on these five variables.
[b] Interval data.

Table 3
Pearson correlations between the measured variables ($N = 54$).

	1	2	3	4	5	6
1. SE						
2. IG	.39**					
3. EG	−.01	−.29*				
4. RL	.12	.16	.02			
5. PAS	−.25	.12	−.27*	.24		
6. Magnet	−.03	.11	.13	−.03	.03	
7. KWL_s	.10	−.51**a	.13	−.16	−.16	−.19

Lower figures correspond to higher values of the measures on the first five variables.
* $p < .05$.
** $p < .01$.
[a] As the lower figures correspond to the higher values of motivation, the negative correlation actually indicates the positive relation between students' intrinsic motivation and their engagement in filling up the KWL table.

distribution of all of the nine measured variables is normal (i.e., the null hypothesis can be accepted) (Warner, 2007).

Table 3 shows that the Pearson correlations between the seven variables. Some significant associations among them are found. First, among the self-reported motivation and metacognition variables, students' self-efficacy beliefs in learning the concept of magnet are positively correlated with their intrinsic motivation. The negative correlation between their intrinsic motivation and their extrinsic motivation is moderate. These results are consistent with the contemporary views and empirical findings about the relationships between those elements of motivation (Schunk et al., 2008), suggesting that the concurrent validity of this SRL instrument is acceptable.

The Pearson correlational analysis uncovers that none of the motivational variables statistically predicts students' achievement in learning the concept of magnet (see Table 3), although those variables were measured in the context of learning that concept. However, a significant relation was revealed between students' intrinsic motivation and KWL_s, a measure on the degree to which the students engaged in and completed KWL in the mobile learning processes. In the coding scheme used, a high score on a motivational variable actually indicates a low value of that variable. Accordingly, the negative correlation between the scores on intrinsic motivation and the KWL_s scores shown in Table 3 actually demonstrates that the more the students were motivated intrinsically in studying the concept magnet, the more efforts they had invested in answering the KWL questions.

Table 3 also shows that a weak, but statistically detectable correlation can be found between PAS and extrinsic motivation. Specifically, the higher perceived autonomy supports from parents they reported, the weaker extrinsic motivation of learning the topic of magnet they had, empirically implying a correlation between perceived parental autonomy support and student academic motivation.

Based on the initial analyses, a series of separate logistic regression models were used to further validate the relations of KWL_p with (1) each of the four SRL measures, (2) the parental autonomy support (PAS), and (3) student score on the concept magnet (magnet_score). The mean of student scores on magnet is 5.18, and its small standard deviation is 1.01 (shown on Table 2). Technically, the most considerable advantage over other statistical techniques such as ANOVA in this case is that in logistic regression the independent variables (predictors) do not have to be normally distributed, linearly related, and of equal variance within each group (e.g., answering the KWL questions vs. not answering the KWL questions) (Tabachnick & Fidell, 2007). Conceptually, these six predictors can be classified into three groups of predictors: SRL measures, parental autonomy support, and student achievement in learning the magnet. Three sets of logistic regression models were used in the present study. One set consists of four measures on SRL (i.e., self-efficacy, intrinsic motivation, extrinsic motivation, and regulation of learning). Any one of the other two has only one predictor separately: PAS and magnet_score.

First, four separate logistic regression models were run to test if any of the four SRL measures) can predict whether individuals were involved in filling up the KWL table (i.e., KWL_p). In order to control the cumulative Type I error that may be generated by the four separate regression models, the alpha level (threshold) was adjusted to .0125(.05/4) in this case given the original alpha level is set at 0.05 according to Bonferroni adjustment (Warner, 2007). Then, two separate logistic regression models were used to test if (1) PAS can statistically predict KWL_p, and (2) KWL_p can statistically predict magnet_score. In order to avoid another extreme – Type II error, the conventional alpha level (.05) remains within the other two separate regression models, since unlike the four SRL measures, parental autonomy support and learning achievement correspond to two qualitatively different psychological processes.

Table 4 displays that in the category of self-reported SRL, only can extrinsic motivation statistically predict whether or not the students were involved in answering the KWL questions even after the Bonferroni adjustment of alpha level (.05/4 = .0125). Table 5 shows the students who answered at least a KWL question (regardless of how deeply they engaged in it) reported lower extrinsic motivation than those who did not answer any KWL question at all (lower figures indicate higher value). Meanwhile, parental autonomy support is statistically associated with KWL_p. Specifically, the group of students who answered the KWL questions reported higher perceived parental autonomy supports than those that did not answer any KWL question (see Table 5 in which lower figure indicate higher value). Student achievement in learning the concept of magnet can be statistically predictable by whether or not they answered the KWL questions regarding the magnet. The students that filled up the KWL table obtained higher scores on the items for magnet in the final examination than those that did not touch the KWL table at all.

In sum, the quantitative analyses have yielded three significant empirical findings. First, individual students' intrinsic motivation and extrinsic motivation play different roles in initiating and sus-

Table 4
Results of the logistic regression models on categorical variable of KWL.

Predictors	Model estimates ($N = 67, df = 1$)		Parameter estimates ($df = 1$)				
	χ^2	p	B	SE	Wald	p	Exp(B)
SRL measures							
Self-efficacy	.630	.427	−.288	.365	.621	.431	.750
Intrinsic motivation	.396	.529	−.234	.373	.393	−.234	.373
Extrinsic motivation	7.642	.006	.805	.313	6.616	.010	2.237
Regulation of learning	.009	.926	−.027	.291	.009	.965	.971
PAS	5.163	.023	−.881	.419	4.427	.035	.414
Magnet score	4.408	.036	.606	.306	3.920	.048	1.833

Table 5
Scores of magnet test, extrinsic motivation, and parental autonomy support in the two categories of KWL.

	Magnet score	Extrinsic motivation[a]	Parental autonomy support[a]
Having KWL	5.56	2.52	2.11
Not having KWL	4.82	1.89	2.48

[a] Lower figures correspond to higher values of the measures on both extrinsic motivation and PAS in this case.

taining their engagement in answering the KWL questions. Specifically, whether or not the students are involved in answering the KWL questions can be accounted for by their extrinsic motivation, meanwhile, to what degree they will actively engage in the initiated mobile learning is significantly associated to their intrinsic motivation. Second, the effect of students' self-reported motivation on their learning achievement is mediated by their engagement in answering the KWL questions. Third, students' perception of parental autonomy support is not only associated with their motivation in school learning, but is also associated with their actual behaviors in self-regulating their learning (by filling up the KWL table).

5. Discussion

The theoretical and empirical analyses help us establish two basic conclusions. First, theoretically, SRL does provide a conceptual framework for qualitatively understanding the nature of mobile learning as well as the analysis of the student-centered mobile learning processes. Second, empirically, according to our analytic SRL model of mobile learning, the quantitative measurement and analyses reveal the relationships between the three profiles of student learning occurring in the mobile devices: students' self-reports of psychological processes, patterns of online learning behavior in the MLE, and learning achievement. Specifically, the empirical findings reveal the essential role of students' behavioral engagement in the KWL table in mediating the relationship between their motivation of learning and perceived parental autonomy support, and their learning achievement. Winne's phase model of SRL (2001) explains the mechanism in which the KWL table as a metacognitive tool scaffolds and fosters students' cognition, metacognition, and motivation while they are engaged in learning in the mobile learning environment.

Concerning the challenge of the under-theorization about the nature, processes, and outcomes of mobile learning, the present study contributes to addressing this challenge from both the qualitative and quantitative perspectives (Sharples et al., 2005, 2007; Wali et al., 2008). It demonstrates the potential and prospects of conceptualizing and analyzing mobile learning processes from a theoretical stance. It empirically suggests what the internal and external factors underlying the mechanism of mobile learning might be. In a broader sense, the present study enriches our knowledge about the mechanisms underlying students' learning with technologies, which is lacking in comparison to the technological advances that have made these same environments commonplace at home, in school, and at work (Azevedo, 2005).

A remarkable finding in the present study is that whether or not the students worked on the KWL table (regardless of how much they worked on it) can be accounted for by their extrinsic motivation. Once they started to work with the KWL question(s), how deeply they engaged in the KWL questions can be predicted by their intrinsic motivation. These findings uncover the different roles played by intrinsic motivation and extrinsic motivation in initiating and maintaining students' learning actions in this MLE. This is congruent with the finding in the SDT research – intrinsic motivation fuels students' engagement and learning (Reeve et al., 2008). A tentative interpretation is that when the students in the two classes had a choice in filling in the KWL table and realized it is not directly associated with their examination scores, the students with high extrinsic motivation tended to ignore the KWL table and those with low extrinsic motivation tended to complete it.

A straightforward implication for designing effective student-centered MLE is that in order to enculturate students to motivationally and metacognitively engage in learning activities, the design elements should lessen their extrinsic motivation and yet boost intrinsic motivation. By definition, intrinsically motivated people engage in an activity because they find it innately interesting and enjoyable. In contrast, extrinsic motivation leads people to engage in an activity as a means to attain some external outcome such as a reward or avoidance of punishment (Ryan & Deci, 2000). Normally, a high grade that will please students, their teachers, or parents can be regarded as an external reward. Students who attach much importance to such a high grade will usually self-report high extrinsic motivation from the perspective of measurement. The finding that students' extrinsic motivation is negatively correlated with their perceived parental autonomy supports indicates that extrinsic motivation could be reduced to some degree if they can perceive a certain level of parental autonomy support. The lower the extrinsic motivation a student possess, the more likely she would be willing to work on the KWL questions. The more likely a student is motivated to engage in the motivational and metacognitive process (by answering the KWL questions), the more likely she will attain a high score. A basic conclusion herein can be that an effective student-centered MLE needs to include elements of parental autonomy support that are conducive to lessening extrinsic motivation.

The unique contributions of SRL to theoretically and empirically understand and analyze mobile learning should be essentially attributable to the notion of human agency – the fundamental theoretical assumption of SRL. It informs that effective mobile learning environments can be designed to allow and offer learners some freedom of choice in learning processes such as self-perceiving assigned tasks, setting their own goals and plans of learning, monitoring and controlling cognition and behavior, and so on.

Thus, the notion of agency is the key to making sense of those empirical findings the present study has obtained. During the 5-week lessons on the magnet, the teachers encouraged but did not require the students to fill in the KWL table in their mobile devices. Essentially, the students were given a degree of freedom in controlling their motivational and metacognitive behaviors by setting their goals of learning and monitoring the state of learning, namely, self-regulating their own learning. In this sense, the teachers were autonomy-supportive, since they actually provided a pedagogical condition that supports students to experience/sense autonomy (Reeve et al., 2008). Research in SDT reveals that autonomy-supportive classroom contexts nurture students' intrinsic motivation. Although the present study does not have empirical data directly demonstrating if the autonomy supportive classroom promoted students' intrinsic motivation, the finding that the students with lower extrinsic motivation expressed more willingness to do the KWL than those with higher extrinsic motivation is at least not inconsistent with SDT logically. Alongside the moderate negative correlation between students' intrinsic motivation and extrinsic motivation found in the present study, it can be inferred that classroom/pedagogical autonomy support is conducive to stimulating and nurturing students' self-regulation in the mobile learning environment.

Classroom autonomy support is an autonomy support for SRL occurring in the formal learning settings. Ubiquity naturally entails learners are motivationally, cognitively, and metacognitively engaged in mobile learning activities across settings. When students work on the mobile devices with their parents at home, the parental autonomy support is presumably associated with their motivation and actions in learning. In the present study, the statistically detectable correlation between students' extrinsic motivation and their perceptions of the autonomy supports from their parents essentially suggests that the link between students' achievement motivation in classrooms (formal settings for learning) and the perceived parental autonomy supports while they interact with their parents in the family activities (informal settings for learning). A potential significance of these empirical findings is that this is empirical and quantitative evidence bridging the measures in two settings of learning (formal vs. informal).

The mediating role of the built-in KWL table in the relations between student motivation, perceived parental autonomy support, and learning achievement optimally manifests Bandura's reciprocal determinism in the context of mobile learning. The unique importance of KWL is attributable to the mechanism under which how the KWL table functioning as a combination of metacognitive and motivational actions in real-time guides the students to go through a SRL process in mobile learning.

Since students' engagement in the KWL questions can be viewed as a behavioral index of motivation (Schunk et al., 2008), the present study indicates the impact of students' self-reported motivation on their learning achievement is mediated by online motivation in the authentic classroom learning. This empirical work is aligned with Zimmerman's call for the second wave of research in SRL, which is methodologically aimed to address the main challenge SRL researchers are facing by developing online measures of SRL processes in authentic contexts (Zimmerman, 2008). Since SRL is viewed as dynamic and recursive processes, state-oriented methods like self-report surveys have severe limitations in unobtrusively capturing the process data of online SRL in technology-advanced learning environments like mobile learning (Winne, Jamieson-Noel, & Muis, 2002; Winters, Greene, & Costich, 2008). The present study illustrates how SRL theories (e.g., motivational constructs) and methodology (e.g., a combination of self-reports and observed online behavioral data) can help us analyze and understand the mobile learning process.

Two main limitations of the present study are recognized. First, the present study merely relies on quantitative measurements. Further analysis of the qualitative data and descriptions of what and how the students actually learned, and how they interacted with peers and teachers in and out of classroom is needed in the follow-up studies. Second, some multivariate statistical techniques like SEM (structural equation modeling) could have been used to frame the findings in a more coherent manner if the sample size was larger.

Finally, we have a fundamental assumption behind the present study, which is knowledge and skills of SRL are a precursor to mobile learning, as well as a primary outcome of mobile learning. However, in fact, research has revealed that learners of all ages have difficulties in applying key self-regulatory skills during learning about complex and challenging topics when they are embeded in the open-ended learning environments (Azevedo, 2005). More empirical research is required to figure out what kinds of scaffolds are effective in facilitating SRL and when they are best deployed in mobile learning environments. The revelation of the importance of the KWL in the present study as a metacognitive tool in mediating the relationship between student motivation and learning achievement enriches our knowledge about what kinds of scaffolds are useful, how and when they are optimally applied for fostering students' SRL knowledge and skills.

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Appendix A. A four-subscale survey questionnaire on self-regulated learning

A.2. Self-efficacy beliefs

1. I believe I am able to learn the concepts of magnet well.
2. I'm certain I can understand the concept of magnet being taught in the coming weeks.
3. I'm confident I can learn the concepts of magnet well that are being taught.
4. I expect to do well in the lessons about the concepts of magnet.
5. I'm confident I can understand the most difficult concepts of magnet.
6. I'm confident I can do an excellent job on the assignments and tests about the concepts of magnet.

A.3. Intrinsic motivation

1. Even when completing the assignments does not guarantee that I get a good grade, I still love to complete them.
2. The most satisfying thing for me in the lessons on the concepts of magnet is trying to understand what I should be learning as much as possible.
3. I am interested in learning the concepts of magnet.
4. In the lessons on the concepts of magnet, I prefer learning about things that will challenge me so that I can learn new knowledge.
5. In the lessons on the concepts of magnet, I prefer learning about things that will arouse my curiosity, even if it is difficult to learn.
6. Even when participating in the learning activities does not guarantee that I get a good grade, I still love to participate in them.

A.4. Extrinsic motivation

1. Getting a good exam score on the concepts of magnet is the most satisfying thing for me right now.
2. My main learning goal in the lessons about the concepts of magnet is getting good results.
3. I want to learn the concepts of magnet better than my classmates.
4. I normally will only learn the concepts that will be tested even though they are much interesting to me.
5. If I can, I want to get higher examination scores in answering questions about concepts of magnet than most of my classmates.
6. I want to do better than other classmates in this class because it is important to show my ability to my parents, friends, or others.

A.5. Regulation of learning

1. When studying the concepts of magnet, I will normally set learning goals for myself so that I can decide how and what I want to learn.

2. When learning the concepts of magnet, I will normally study in a place where I can concentrate.
3. I will normally ask myself questions to make sure I understand the concepts of magnet.
4. When studying the concepts of magnet, I will normally try to identify the concepts that I do not understand well.
5. When studying the concepts of magnet, I will normally ask myself questions to help me focus on what to study.
6. When I am not sure about any concepts of magnet, I will go back and try to figure it out on my own.

Appendix B. A parental autonomy support survey

This scale is a modification of the parental autonomy support survey developed by Soenens et al. (2007).

1. My parents listen to my opinions when I work together with them on the smart-phone at home.
2. My parents let me make my own plans for I want to do when I work together with them on the smart-phone.
3. My parents are usually willing to consider things from my point of view when I work together with them on the smart-phone.
4. My parents are sensitive to many of my needs when I work together with them on the smart-phone at home.
5. My parents allow me to choose what to do with the smart-phone whenever possible.
6. My parents allow me to decide things for myself when I work together with them on the smart-phone.
7. My parents insist upon their way when I work together with them on the smart-phone (reversed).

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