Improving a Mobile Learning Companion for Self-regulated Learning using Sensors

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Abstract: The ability to efficiently manage learning is linked to positive learning experience and outcome. However, attaining the ability of self-regulating is not a matter of course for students and it requires an external assistance. A learning companion stemming from intelligent tutoring system (ITS) has non-authoritative, co-present effect as a learning support and with available sensor technology, self-regulated learning can be better promoted. Sensor enhanced learning companion can detect learning states, learning behaviours and context and provide valuable feedback to learners to increase their awareness of learning progress and to effectively manage their learning. Considering the mobility, autonomy of learners along together with current trend in open online learning resources and contents, available embedded sensors are suitable for realising the concept of learning companion for self-regulated learning. The paper reviews a self-regulated learning concept, a learning companion pedagogy and proposes sensor technology for self-regulated learning and learning companion design considerations.

1 INTRODUCTION

Successful learning does no longer depend on lack of learning resources or contents nor types of technology, whereas it remains on availability of learning support and learner's ability to motivate and manage learning. Learner's determination and regulation on what to know and how to learn becomes an especially important skill for learners with constant distractions, especially when students tackle their learning contents in various places and time of their choice. Hase and colleagues advocated the need of learner centric learning environment approach (Hase and Kenyon, 2001) and various recent research (Fernandez-Rio et al., 2017; Lee and Recker, 2017; Kizilcec et al., 2017; Guy et al., 2017; Mega et al., 2014) discussed the importance of self-regulated learning for successful learning.

The aim of this position paper is to discuss the possibility of promoting self-regulated learning using a learning companion pedagogy and the possibility of improvement of a learning companion for self-regulated learning using current available sensor technology. The paper will first present previous studies on self-regulated learning and learning companion.

Following the literature review, sensors which can provide information on the state of the self-regulated learning are discussed to suggest the feasibility of self-regulated learning support using current sensor technology. Lastly, based on the literature on learning companion and newly found limitation on sensors for self-regulated learning state detection, the paper discuss the design consideration for a learning companion to facilitate self-regulated learning support using sensors.

2 STATE OF THE ART

2.1 Self-regulated Learning

Self-regulated learning is a process where a learner autonomously converts intellectual competence to academic proficiency through control of thoughts, feelings and behaviours based on a set goal (Zimmerman, 2002). When faced with a learning task, a self-regulated learner will actively follow four phases explicitly or in a tacit way (Pintrich, 2004) : 1) forethought, planning and activation, 2) monitoring, 3)

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control and 4) reaction and reflection. All phases concern learner's cognition, motivation, behaviour aspects along with context for external learning surroundings. Self-regulated learning includes how to attain knowledge better as well as how to control learners' emotion and motivation. Therefore, metacognition which deals with knowing how to cognitively learn is a component of a self-regulated learning framework as well as meta-motivation (how to motivate oneself).

Although having self-regulated learning skills is helpful, challenges remain. Zimmerman (2002) discussed few instructors engage learners to be equipped with effective self-regulated learning skills and learners are not often provided with choices to choose their own learning task. Trainings for self-regulated learning ability are available, yet trainings are mainly provided within a specific learning content or as a general skill which are difficult for learners to apply in other tasks of their choice.

As a mean to facilitate self-regulated learning, Azevedo and Cromley (Azevedo and Cromley, 2004) advocated the possible integration of self-regulated learning process in a learning companion which provide a feeling of non-authoritative, friendly pedagogical support for learning enhancement.

2.2 Learning Companion

Learning companion is a non-authoritative educational agent that has human characteristics to facilitate social learning. The concept of learning companion derived from an intelligent tutoring system (ITS) and the term, pedagogical agent is interchangeably used in related research. The main role of ITS is providing an appropriate one-on-one feedback to learners by taking a specific role (domain export, student, pedagogical or interface) (Wenger, 1987). Similar to other ITS, the study on learning companion explains the role of learning companion as a peer and available collaborator that encourages students to learn cooperatively (Goodman et al., 2016). Additionally, another study introduces three roles of learning companion as competition, suggestion and collaboration. Competition refers to competing with peer in a form of comparing their work with each other upon independent work (Chan and Baskin, 1988). Suggestion role is to collaboratively work and observe each other's work. Collaboration role refers to collaborative work with shared responsibility.

The difference between ITS and learning companion is not easily distinguishable as the common interaction behaviours such as coherent dialogue with a student and pedagogical decision making regarding on what information and when to provide can be found in studies in ITS, pedagogical agent and learning companion (Johnson et al., 2000). 5 types of learning companions (PHelpS, People Power, Distributed West, LC and SAM) were reviewed and they reveal unique interaction characteristics between a system and a learner:

- PHelpS (Peer Help System) : It offers assistance to find others to provide help in learning and it mediates communication without being directly involved in learning activities (Greer et al., 1998).
- People Power : It questions students to seek answers by themselves and interacts with a student as a co-learner (Dillenbourg and Self, 1992).
- Distributed West : It acts as a non-adaptive coach, allowing students to see each other in a system and play as learning companions (Chan et al., 1992) .
- LC : It initiates a dialogue and starts with a rapport building. During learning, it intervenes and a learners is provided with learning status and learning strategy use (VanLehn et al., 2016).
- SAM : It has learner's characteristics such as age and communicate style and initiates dialogue with a learner. It takes turns to communicate and encourages a learner with compliments (Ryokai et al., 2003).

Learning companion guides learners through communication (PHelpS, People Power, LC, LuCy and Sam) and it uses various pedagogical strategies to motivate and provide opportunities for learners to reflect (LC, LuCy and SAM). The most distinctive difference between other ITS and learning companion is the non-authoritative, co-learner characteristics. Unlike ITS, students perceive learning companion as a fellow student or peer who has similar knowledge level (Ryokai et al., 2003). It also cares about a learner's progress and shows social connection by working together and shows emotions to make learners interact with them continuously (Woolf et al., 2009). However, the current research on learning companion is limited to a single subject (domain), therefore the design of learning companion which can integrate numerous domains continuously to stay as a lifelong friend should be explored (Chou et al., 2003). The following section explores mobile device platform for learning companion.

2.3 Mobile Learning Companion

Usage of mobile device in daily life has been grown and the device has been penetrated in various aspects in life. The statistics shows that more than 70 % of people in America own smartphone in 2016 and smartphone dependency over time is gradually growing (PewResearchCenter, 2017). In Europe, the similar phenomena can be observed. The number of people using internet on the move by using mobile devices has grown to 57 % in 2015 compared to 36 % in 2012 (Eurostate, 2016).

For learning, mobile learning provides a personalised, unobtrusive, instant way for learners to access learning materials and tools and extends the availability of education to all people (Traxler and Kukulska-Julme, 2005). Searching for information is possible anytime using a mobile device and sharing information became much more instant and intuitive. The mobile device provides a rich learning contents in inexpensive way to people and it serves a key role to make information globally accessible (Wellman, 2007). People do not need to sit or even be in one place to learn but they can learn whenever they want and wherever they want.

The mobile device also proposes a distinctive opportunity to support learners continuously at the appropriate time. Available technology in a mobile device allows learners to interact with others online, share their work with others and with other devices in learners' household. Information can be found easily and scheduling with alert function helps learners manage their time. The embedded sensors in a mobile device are also a beneficial means as they provide information regarding on learner's location and state. Current learning companion systems are designed mainly on stable devices (computer), which fails to consider mobility of learners.

Goodman and colleagues proposed the importance of designing a learning companion which can interact with learners in more natural way (Goodman et al., 2016) and considering learners' mobility in learning environment can be fulfilled by investigating a mobile technology. With the progress of technology advancement, more affordable, refined sensors will be embedded in a mobile device which will serve a good tool to realise a learning companion.

3 SENSORS FOR A MOBILE LEARNING COMPANION

Smartphone that people carry contains at least 15 sensors which detect user's behaviour and context which can monitor learner state and context in unobtrusive ways. This part proposes that sensors can support self-regulated learning and how a learning companion should be designed to serve as an effective interactive co-learner.

3.1 Sensors for Self-regulated Learning

Based on the self-regulated learning framework (Pintrich, 2004), sensors that are used in health, learning and everyday life have been reviewed and identified as possible sensors to detect each self-regulated learning state as shown in the Table 1.

Table 1: Sensors to detect self-regulated learning area and phase (Cog. : Cognition, Motiv: Motivation, Prox.: Proximity Sensor, HR : Heart Rate Sensor, Accel.: Accelerometer, Mic.: Microphone, EDA: Electrodermal Activity Sensor, Light: Ambient Light Sensor).

	Cog.	Motiv.	Behaviour	Context
1	-	-	-	Bluetooth Prox. Light
2	Camera Prox.	Camera HR	Camera Prox.	Camera Mic. Prox.
3	Mic.	Mic. EDA	GPS Wifi Touch Accel. Gyro Prox. Baro	Mic. Prox. Gyro Baro GPS Wifi Accel.
4	HR EDA	Camera EDA HR	-	-

Sensors such as camera can detect learner's control phase (phase 2) for all areas(cognition, motivation, behaviour and context) of self-regulated learning. For instance, camera can recognise a learners' gaze, a presence of a user and facial expression (Horvitz and Apacible, 2003). Detection of learner's attention to learning material can be done through gaze detection (Sharma et al., 2016). A wearable camera can recognise learner's behaviour, specifically the task that he or she is involved in (Fathi et al., 2012). Camera on a smartphone could detect physiological state such as fatigue (He et al., 2013). Emotion detection is possible with a camera by detecting head position and movement (Woolf et al., 2009). Mobile application, inSightDemo (shown in Figure 1) uses front end camera to detect facial expression and shows 7 states (neutral, happiness, surprise, anger, disgust, fear and sadness).

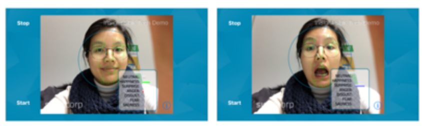

Figure 1: InSightDemo (AppStore).

Microphone is also widely used to detect ambient noise, context and activity of users. In one study, microphone is used to define learners' activity by relating speaking behaviour with being in a conversation (Siewiorek et al., 2003). It also detects and validates the use of self-regulated learning strategy (phase 3). For instance, learners' positive self talk to boost their self-efficacy (Bandura, 1997) and minimise negative affect (Zeidner, 1998) to regulate their cognition and motivation can be sensed by microphone.

Contextual information such as perceiving learning environment can be detected through Bluetooth, proximity sensor, camera and ambient light sensor. Proximity and ambient light sensors detect the brightness, artificial sources and the presence of other people or object (Schmidt et al., 1999). Bluetooth used in Miluzzo's study detects the people who are using the same mobile application and provides feedback to learners to provide contextual information .

Motivation awareness and monitoring (phase 2) can be detected using a heart rate sensor and galvanic skin conductance (or electro dermal activity sensor so called EDA) (Mandryk and Atkins, 2007). Especially for cognition and motivation monitoring, heart rate and EDA sensor can be used (Mandryk and Atkins, 2007). Even though current EDA sensor is restricted in a wearable technology which needs to be resolved for unobtrusive monitoring, the heart rate sensor has been adopted in current smartphone using a rear end camera (Samsung, 2016).

Location of a person and user's activity inference through detecting the location of the sensor device can be realised through WiFi, GPS and touch sensor (Kern and Schiele, 2003; Miluzzo et al., 2008; Ben-Zeev et al., 2015; Hinckley et al., 2000). Learner's forfeiting behaviours can be detected using Wifi, GPS and touch sensor as giving up refers to leaving the place where they set to study and enabling a mobile device which can distract them from learning. Also learner's action to change or leave a context to control their learning environment can also be detected using GPS, WiFi, accelerometer and even gyro and barometer sensors.

Comparison of heart rate and EDA between the beginning and the end of the learning can also provide learners with awareness of their learning. Furthermore, camera used for gaze and facial expression can provide additional information on learner's attention and affective reaction during learning. Context detection and location information that have been altered during learning can be used to evaluate the task and learner's behaviour. Overall, reaction and reflection stage (phase 4) of self-regulated learning can be fostered by providing various combination of sensor data, mentioned previously. However, various areas, especially phase 1 of self-regulated learning, are difficult to correlate with sensors as they refer to perception of task, perception of context, task value, planning and goal orientation.

The sensor technology can provide non-invasive information to support learning, especially for self-regulated learning. Nonetheless, for a learning companion to be served as a scaffold to facilitate learning, comprehensive self-regulated learning areas and phases should be considered for design.

3.2 Design Consideration for a Sensor based Learning Companion

The limitation from sensors integration for learning support as discussed in the previous section and the need for an adaptive feedback can be resolved by introducing a learning companion pedagogy. For instance, the learning companion system, Sam, enhanced learning experience by using sensors. Sam engaged younger learners in a storytelling task by using radio frequency tag embedded in a learning resource and a microphone to take turns (Ryokai et al., 2003). Sam integrated sensors technology to use a learning resource cooperatively with a learner and also communicate with him or her in a way that a learner perceives Sam as a peer and even a human.

Sensors adopted in a learning companion also detect physiological state such as stress level and a companion provides messages to relieve stress and continue engage in learning even learners are facing difficult tasks (Prendinger and Ishizuka, 2005). This empathic companion co-exists with a learner and maintains a long relationship with a learner by providing an emotional support.

For a learning companion to be successful in connecting with a learner and maintains a relationship, design consideration should be made. Especially, the design of learning companion should consider the missing links to incorporate overall aspects of self-regulated learning with emphasis on characteristics of learning companion (non-authoritative, intuitive and friendly). Based on the previous studies on learning companion, desirable characteristics of learning companion are as follows:

- A learning companion should correspond to each learner's characteristics (Kim, 2007).
- A learning companion should provide instructional advantages and provide encouragement to learners (Goodman et al., 2016; Woolf et al., 2009).
- A learning companion should initiate dialogue

and force students to engage in reflection (Goodman et al., 2016).

- A learning companion should have a simple and stylish visual with task and relation orientation (Haake and Gulz, 2009).
- Learners should regard a learning companion as a fellow learner and furthermore a real human (Ryokai et al., 2003).
- Learners should enjoy interacting with it and have positive perception of overall learning experience (Woolf et al., 2009).

4 CONCLUSIONS

Learners, with numerous choices in educational contents, can benefit by having self-regulated learning skills as they can support learners to tackle various obstacles that learners face during learning. Training for self-regulated learning skills is possible yet the transfer of this skill in another domain is questionable and not actively enforced. Mobile device that has technical capabilities to detect valuable information related to learning environment, behaviour, cognition and motivation can facilitate learners to become more capable people and have better learning experience. However, as Hase and colleagues emphasised that learning is only possible when learners perceive learning as process of one's improvement and it is guided without threats (Hase and Kenyon, 2001), learning companion pedagogy can be an ideal method to meet current technology enhanced learning environment. Sensor technology can support learners by providing information on their cognitive and emotional state and guide them to choose an optimal behaviour and a suitable ambience for learning.

In this respect, this position paper reviews the concept of self-regulated learning and a learning companion pedagogy and discusses available mobile sensors which can be utilised to detect self-regulated learning aspects. Limitations of sensor utilisation for self-regulated learning were disclosed and the paper proposes design considerations for a sensor based learning companion by considering a learning companion pedagogy. The proposed design consideration for a learning companion is broad however, the aims of this paper are to propose that 1) sensors can detect some areas and phases of self-regulated learning which can support learners to be aware of their learning progress and environment and 2) a learning companion pedagogy should be integrated when designing an effective pedagogical support for learning.

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