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Holistic Design of a Mobile Peer Tutoring Application based on Learning and User Needs Analysis

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Abstract: Research has shown that peer tutoring at the university level could improve students' performance and, enhance their motivation and learning, increase self-determination and learner autonomy, and reinforce conceptual knowledge by providing opportunities for reapplication of concepts. This paper describes the development of a mobile peer tutoring application – Mobile Education Networked Tutoring On Request (MENTOR). We start with a review of literature to identify the relevant affordances that this mobile app should possess. In addition, questionnaires were administered with students studying in higher education to understand the needs of peer tutoring with tutors and tutees. The findings of the survey data showed that a majority of the students are receptive to peer tutoring and found it to be a user-friendly and intuitive method of mobile peer tutoring. One feature of MENTOR is the tutor-tutee matching – tutees are individually paired with tutors by using predictive modeling based on student data. Tutor-tutee matching can be efficiently accomplished via MENTOR mobile application by granting tutees the choice of tutors based on mutual tutor-tutee availabilities, students' background and tutor ratings. The other main features of the mobile peer tutoring application such as online peer tutoring are presented in this study. The study contributes to the application of learning technologies to provide a holistic design for supporting student peer tutoring at the university level.

Introduction

Peer tutoring is a cost-effective intervention that improves both tutor and tutees' academic performance (Song et al., 2018). Research studies on peer instruction (Simon et al., 2012), a method that involves students attempting to explain to one another for their understanding of a topic, has shown positive effects on student learning and supports the development of a deep understanding of the topic. In a meta-analysis study conducted by Leung (2015), peer

tutoring is found to be pedagogically beneficial to both the tutor and tutee at the university level. Similarly, a systematic review and meta-analysis on peer tutoring in medical education conducted by Rees et al. (2016) found that students gained as much knowledge and skills taught by peers or faculty members. Peer tutoring should be supported because it will also enhance the tutors' knowledge and teaching skills (Rees et al., 2016).

Could technologies be used to support peer tutoring? Rosen (2011) highlighted there is increasing use of digital technologies to support learning that appeals to the iGeneration – students born after 1990s who are adept and savvy with digital technologies inclination towards individualized activities and electronic communication. While extensive studies on peer tutoring have been conducted and indicated that tutoring is effective in improving academic achievements, studies that address the use of digital technologies to support peer tutoring have remained relatively unexplored. Among the few research studies reported, De Smet and colleagues (2008) investigated how fourth-year college students e-moderated online asynchronous discussion for freshmen and Sansone and colleagues (2018) found that the arrangement for university students to take turns to be an e-tutor for their groups in a blended course could enhance the class collaborations and interactions. Among online facilitation and tutoring, there are few studies on the use of mobile technologies to support peer tutoring.

To address this research gap, this paper presents a research project that leverages mobile technology to facilitate peer tutoring and integrates predictive modeling to predict the tutoring needs of students in tutor-tutee matching by prescribing suitable peer tutors. A peer tutoring app called MENTOR, which stands for Mobile Education Networked Tutoring on Request, is developed that aims to enhance students' academic experience with coordination of face-to-face tutoring sessions via smartphone and online operation of a remote tutoring session.

This paper explains the approach in the holistic design of MENTOR, which includes design considerations from pedagogical and user needs assessment leading to the technological design.

Learning Behaviors Related to Peer Tutoring

The design considerations start with a review of learning behaviors and theories associated with peer tutoring. We first look at students' help-seeking behaviors.

Help-seeking behaviors

This study involves two related learning behaviors and strategies: students' help-seeking and peer tutoring. Students often face challenges in their learning, among other things, difficulty in understanding a specific concept, not able to solve a problem, or difficulty in applying, evaluating, or synthesizing new ideas. Research studies have reported benefits of productive help-seeking behaviors, such as prevention of potential failure, maintaining learning engagement, and enhancing mastery of learning and autonomous learning (Newman, 2000).

Help-seeking behaviors are multi-faceted in terms of cognitive, affective and social dimensions. From a cognitive perspective, seeking help can be regarded as a self-regulation strategy (Karabenick, 2011) because it often results from an analysis of a student's learning difficulties and challenges. It is part of the process where a person learns to use strategies to become more independent in learning (Karabenick & Newman, 2013). The cognitive analysis entails understanding cognitive challenges and seeking relevant help. However, many students may not be

able to identify their learning difficulty. Take for instance, when encountering problem in learning, if a student knows the level of thinking that is entailed (c.f. the Bloom's taxonomy, Anderson & Bloom, 2001), he or she could make better decision to seek help. If it is a knowledge-level issue, identify a reliable and comprehensible source of information might suffice. If it is at the application level, it requires one to know the conditions or contexts to apply a specific theory or principle.

The affective dimension relates to the sense of agency and control. Help-seeking behaviors can be explained with the self-system theory (Newman, 2000) of three needs: feeling of being cared for (relatedness), feeling of independence in taking charge of own actions (autonomy) and feeling of competence.

The social dimension of help seeking is about knowing whom to approach and the socially appropriate way of seeking help. There are several reasons why a peer could be a preferred choice of help for many students. Some students could be wary that help seeking exposes their weakness to the tutors and could affect their course grades. A peer, on the other hand, has a similar social status (Gazula, McKenna, Cooper, & Paliadelis, 2017) and does not exhibit drastic intimidating power differential. Prior social relationships between peers are important for the choice of peer tutor (Boud & Lee, 2005).

While young children could turn to their teachers, parents, friends, or siblings for help, students from an institute of higher education have access to a more restricted pool of people who possess the disciplinary knowledge and skills. To cater to all students' needs and just-in-time help, the workload of tutors will increase drastically (Westera, Bakker, & Wagemans, 2009). Thus, besides tutors, turning to peers is a viable approach.

Peer tutoring

Peer tutoring refers to "people of similar social status helping others to learn and learning themselves by teaching" (Topping et al., 2013, p 226). It is underpinned by social constructivist perspective of learning. According to Vygotsky (1978), a student learns within his or her Zone of Proximal Development or ZPD, which is the student's current development and his or her potential development when assisted by more knowledgeable others. It can be argued that a student's ZPD is likely to have more significant overlap with the peer's ZPD. Put differently, compared with an instructor, a peer could better understand the challenges and difficulty a student is experiencing and provides explanation at the appropriate level.

Vygotsky's (1978) theory also highlights the importance of social interactions in learning. Providing the social collaborative space of learning for the students could assist their learning. Peer tutoring has been associated with various cooperative and collaborative learning strategies. For example, assigning students to take the role of an e-tutor as part of collaboration script has found to enhance students' participation in online discussion (Sansone, Ligorio, & Bugless, 2018). Reciprocal Peer Tutoring (RPT) strategy (Pigott, Fantuzzo, & Clement, 1986) has also been used to student playing both tutor and tutee roles at different time towards the goal of enhancing academic cognitive gain and improving course satisfaction (Fantuzzo et al., 1989). Besides reciprocal tutoring where tutor and tutees are of similar academic standing and are in the same class, peer tutoring has also been implemented in different formats, such as cross-age or same age (Falchikov, 2001).

Peer tutoring has been found to have a positive impact on various aspects of students' learning, including cognitive, social and affective outcomes. Peer tutoring has been shown to be effective in rectifying misconceptions of operating systems among university students (Cakiroglu & Ongoz, 2017) and produce better learning outcomes (Wong et al., 2003) and students' grade (Morgan, Northey & Khalil, 2017). It could also enhance student responsibility and both individual and group rewards (Falchikov & Goldfinch, 2000), distribute the responsibility for learning to students and empower the e-tutors (Topping, 2008), and improve social skills and relationships among students (Kalkowski, 1995). In terms of affective outcomes, it could improve students' self-esteem and confidence (Kalkowski, 1995), provide emotional support and positive role models (Muir, 2018), and enhance motivation, self-esteem and commitment (Anderson et al., 2000). Near-peer tutoring in medical education has been shown to enhance students' satisfaction with the learning environment (Lin et al., 2017).

Content relevance and characteristics of tutors could affect the effectiveness of peer tutoring (Oda, Onishi, & Sakemi, 2014). The cognitive ability of the peer tutor as well as relational ability are perceived as important attributes of tutors that contribute to success in a statistics course (Cantinotti, Désormeaux-Moreau & Balbinotti, 2017). Thus, the matching of tutors and tutees is an important consideration in peer tutoring.

Design considerations

Considering students' help-seeking behaviors and peer tutoring, we derive a few key affordances that the mobile peer tutoring app should possess (Table 1). By affordance, we refer to Norman's (1988) concept that the design should facilitate the target users' perception such that the functionality and purposes of the features are apparent. We also consult the affordances of technologies that support collaborative learning (Jeong & Hmelo-Silver, 2016)

Table 1. Affordances of the mobile peer tutoring app

Learning behaviors related to peer tutoring	Affordances of the mobile application
Help-seeking behaviors, feeling of autonomy	Facilitates timely help
Self-regulation of tutees, feeling of competence	Direct students to analyze level of understanding for topic or problems that need help
Learning in Zone of Proximal Development (ZPD)	Have a database of potential tutors that with similar ZPD
Feeling of relatedness	Matching of tutors and tutees
Learning through social interactions	Social interaction space for peer tutoring • Asynchronous and synchronous communication channels • Sharing of resources • Monitoring through feedback on the tutoring

What is presented in Table 1 are broad affordances. To elicit the next level of details, we turned to needs analysis by surveying potential users.

Needs Analysis

The proposed MENTOR application offers coordination of face-to-face tutoring sessions using iOS and Android OS smartphone applications and online tutoring. The design of needs analysis and UX study are described in the following methodology section.

Participants

In this study, needs analysis was conducted with the student tutors and student tutees of the various disciplines in order to align the student needs' with the configuration of the proposed peer-to-peer MENTOR smartphone app for peer tutoring. The needs analysis was carried out via an online questionnaire, and the research participants comprised 616 students (314 male, 302 female) from the undergraduate and postgraduate programme. Participants gave their informed consent to participate in the study. Part of the results of this survey study was reported in Chung and Tan (2019).

Needs analysis survey

We asked the participants "On a scale of 1-5, how effective do you think the peer tutoring program was in helping students?" and on the similar scale, "How receptive are you to using a peer tutoring mobile app to find a peer tutor?". Ethics clearance was obtained from the university (IRB 2016-10-31-01). The results (Figure 1) show that the majority of the students perceived peer tutoring to be effective (50.68% somewhat effective; 35.62% very effective). In terms of peer tutoring through mobile devices, there were more participants who were neutral to mobile peer tutoring (49.19%) and less than half of the sample indicated somewhat receptive (33.77%) or very receptive (8.6%). These results are not surprising given that school-organized peer tutoring programs have been in place in the university for several years, whereas mobile peer tutoring is new to most participants.

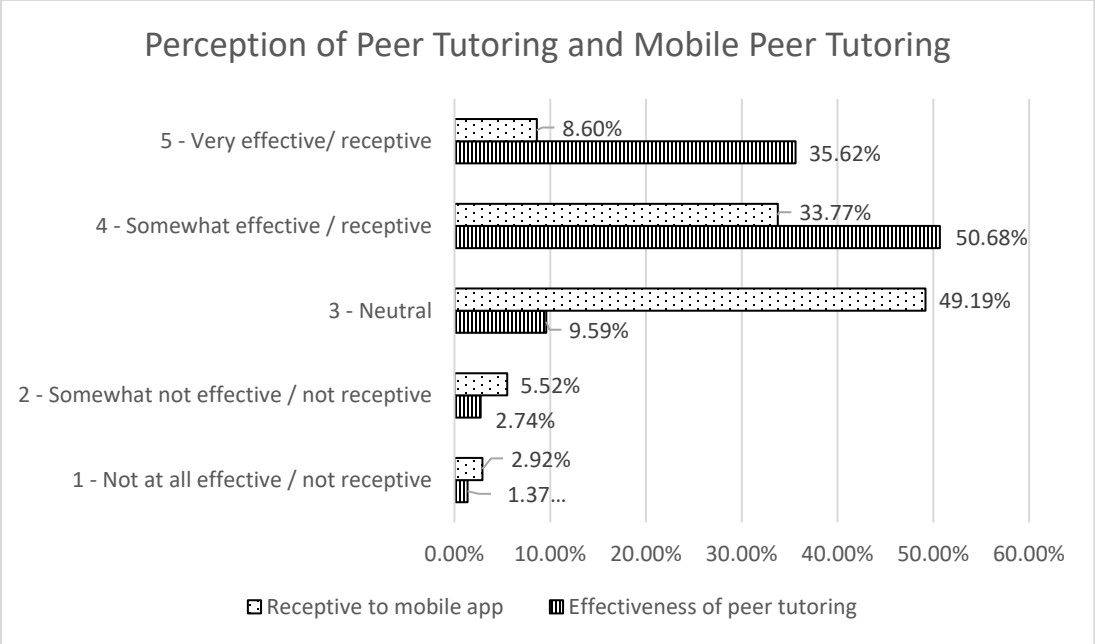


Figure 1. Perception of effectiveness of peer tutoring and receptiveness to mobile peer tutoring

We also probed more in-depth into the reason why the participants go for peer-tutoring. The main reasons why students seek help for peer-tutoring is for understanding tutorial notes (29.9%) and understanding foundational knowledge (23.71%), and a smaller percentage of students was looking for examination tips (15.46%).

To get more specific information to design the mobile app, we ask the participants to indicate features they prefer the mobile application to have (Figure 2). The results show that the followings are among the top choices: sharing of documents (15.4%), text messaging (13.53%), matching of appropriate tutors (11.72%) and seeing tutor's profile (11.35%).

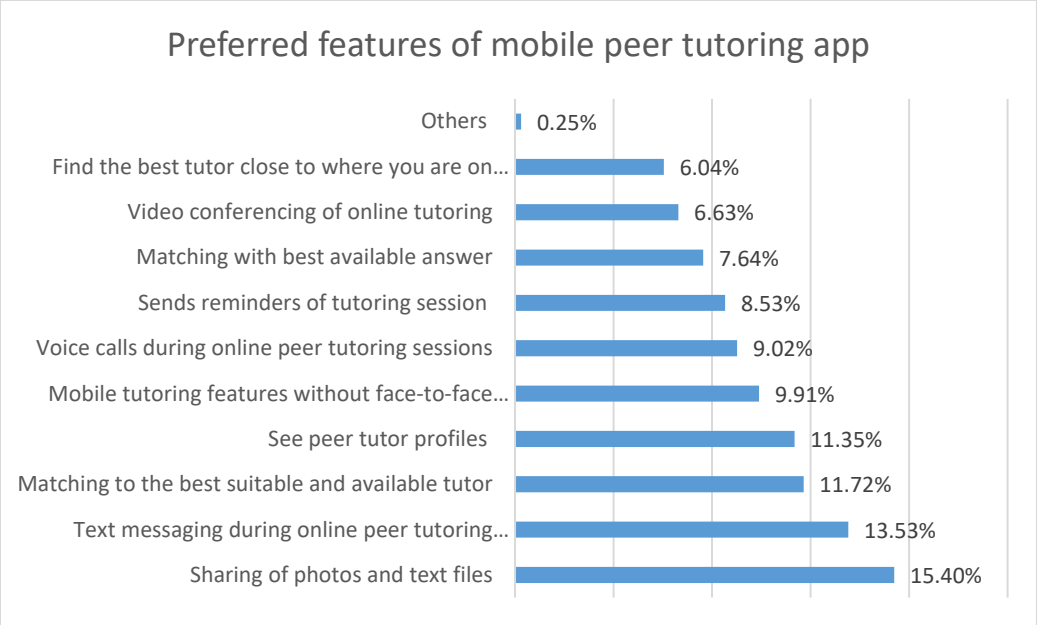


Figure. 2 Preferred features to include in the mobile peer tutoring app

To understand what kinds of tutors the students prefer, we also asked about the preferred characteristics of a peer tutor (Figure 3). The results show that being knowledgeable (18.13%), approachable (17.64%), patient (15.38%), responsive (13.80%) and respectful of the level of understanding (10.59%) are among the top choices.

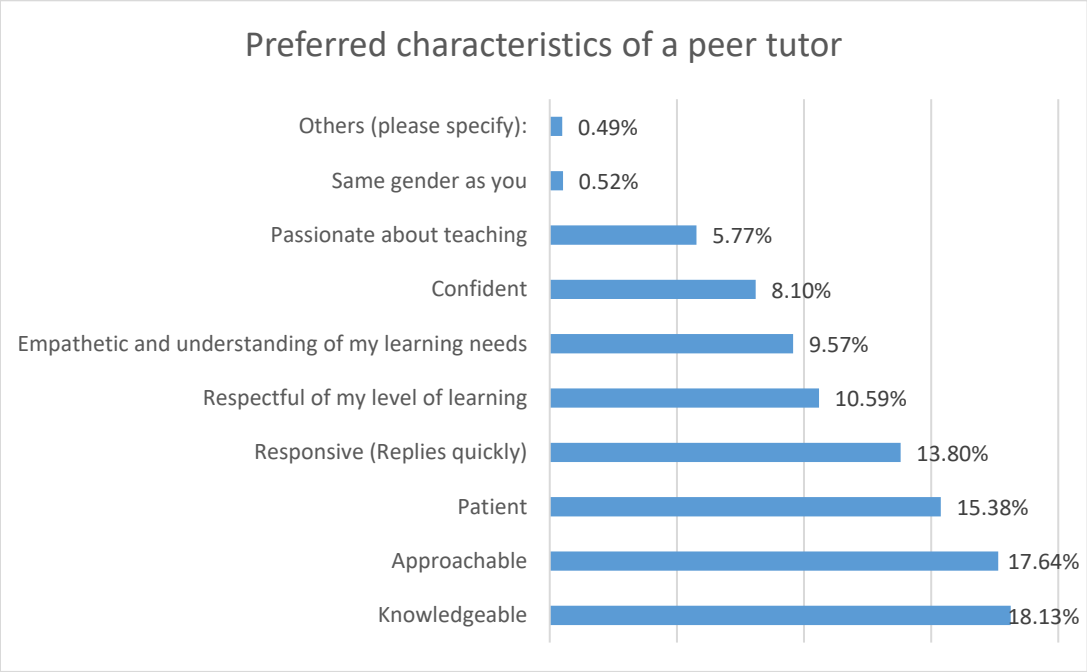


Figure 3. Preferred tutor's characteristics

User experience study

User Experience (UX) research deals with the study, design and evaluation of users after they have experienced the system. It is one of the later human-computer interactions study approach that attempts to move beyond work- and task-oriented approach. According to Bargas-Avila et al. (2011), the study of UX is used to examine people's experience and how they interact with a product. A variety of methods has been employed, including a qualitative study of users' experiences using in-depth interviews and survey followed by quantitative analyses such as ratings of the product based on users' experience and perceptions. In the study on the design of MENTOR UX mobile peer tutoring application, we used several methods, including Service Blueprint, defining Minimum Viable Product (MVP), Affinity Mapping diagrams and creation of User Personas to understand peer tutoring needs, user goals, behaviors and experiences.

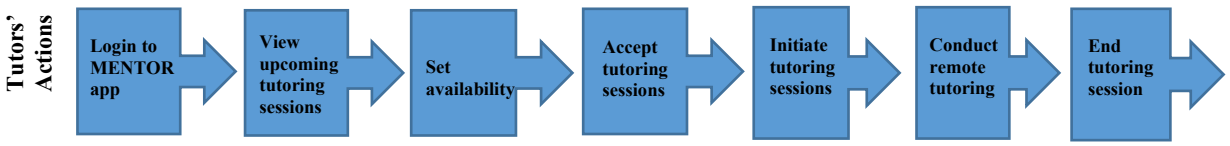


Figure 4. Example of Service Blueprint to visualize tutor journey map in conducting remote tutoring

The use of service blueprint focuses on the users' journey map (e.g. tutor role or tutee role) and visualizes the relationships between different user steps and user journeys for peer tutoring. The essential steps for a tutor interactions include "login to MENTOR tutor account", "View upcoming tutoring sessions", "Set availability", "Accept tutoring session", "Initiate tutoring session", "Conduct remote tutoring", "End tutoring session" as shown in Figure 4. In Figure 5, the minimum viable product (MVP) is used to preliminary identify and validate the MENTOR application in order to gain feedback for future iterations. In this step, we included the minimum features in the MENTOR prototype by conducting tutor/tutees requirements and identifying core functionalities of MENTOR application to test how the target users would respond. In defining the features of the MENTOR app in MVP, the characteristics of a peer tutor derived from the needs analysis are used as one of the factors to define the search criteria in the MENTOR app.

In the UX study, our affinity diagraming process (Figure 6) involved gathering of handwritten notes, ideas, opinions and issues discovered through discussion with past tutors, tutees and tutor managers. Affinity Mapping is a method designed to cluster and bundle ideas in organizing information into groups and clusters based on their relationships. Through brainstorming among teaching staff, we identify several challenges faced by tutees and understanding students learning preferences by grouping the data gathered based on discussions, idea-generation and brainstorming sessions.

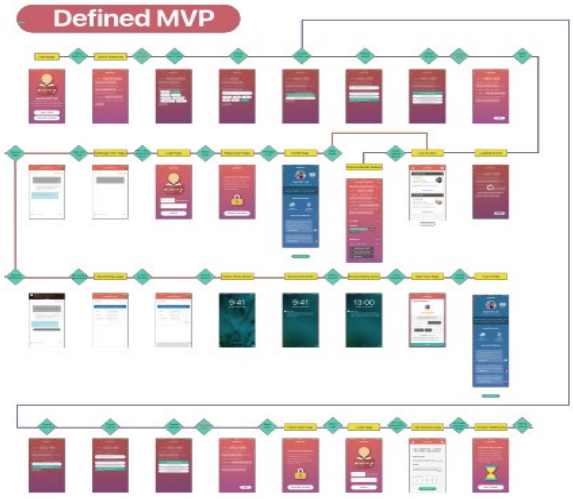


Figure 5. Minimum Viable Product (MVP)

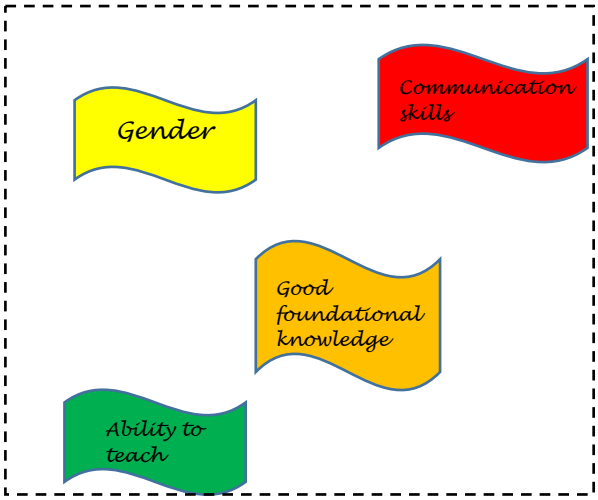
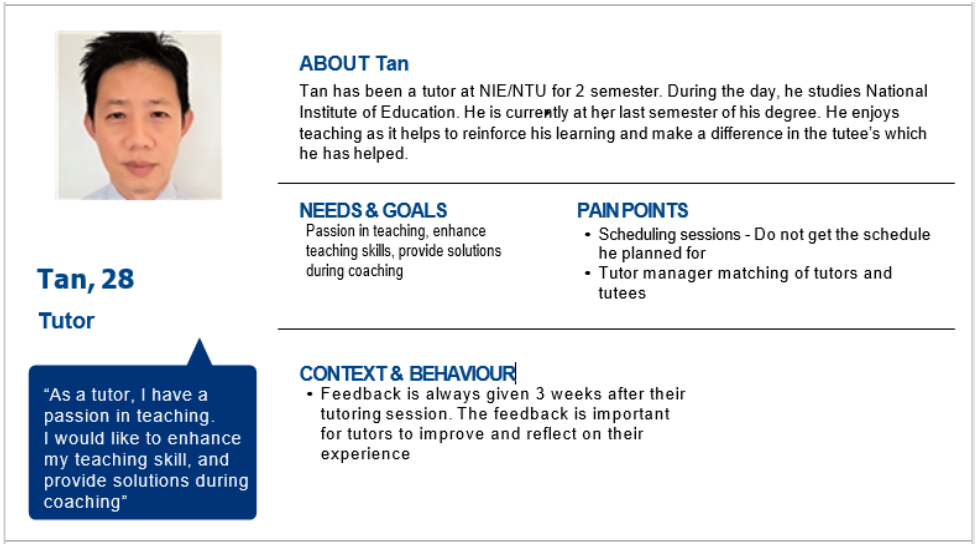


Figure 6. Example of Affinity Mapping Diagram for defining tutor characteristics



(i) Tutor's Persona

(ii) Tutee's Persona

Figure 7. User Personas used in the study (i) Tutor, (ii) Tutee

In Figure 7, the creation of User Personas plays an important step in determining the goals, characteristics and the needs of a larger group. Examples of user personas defined in our study are (i) Tutors, (ii) Tutees and (iii) Tutor Manager.

Design of the Mobile Peer Tutoring Application

Following the learning and user needs analysis, the main affordances and features of the MENTOR mobile application are identified. In this paper, we illustrate two main features: tutor-tutee predictive analytics and online tutoring platform.

Tutor-tutee predictive analytics

In the "Tutor/Tutee Login" screen, a user is greeted by a welcome page and invited to login to the tutor/tutee account to retrieve the student's profile information accordingly. The tutors can be seniors with a strong academic record who provide support to other students or students who have expertise in a specific topic. The tutees who have difficulties in certain topics of coursework will indicate that they require help in tutoring in terms of course content, lecture, tutorial or laboratory. These attributes are useful for predictive analytics in identifying tutors who have general skills required for the subject of interest to coach the tutees. In our needs analysis study, tutors' attributes,

which play an important role in tutor-matching, include good foundational knowledge, able to teach (e.g. good communications skills, illustration with good examples) and the ability to identify learners' needs.

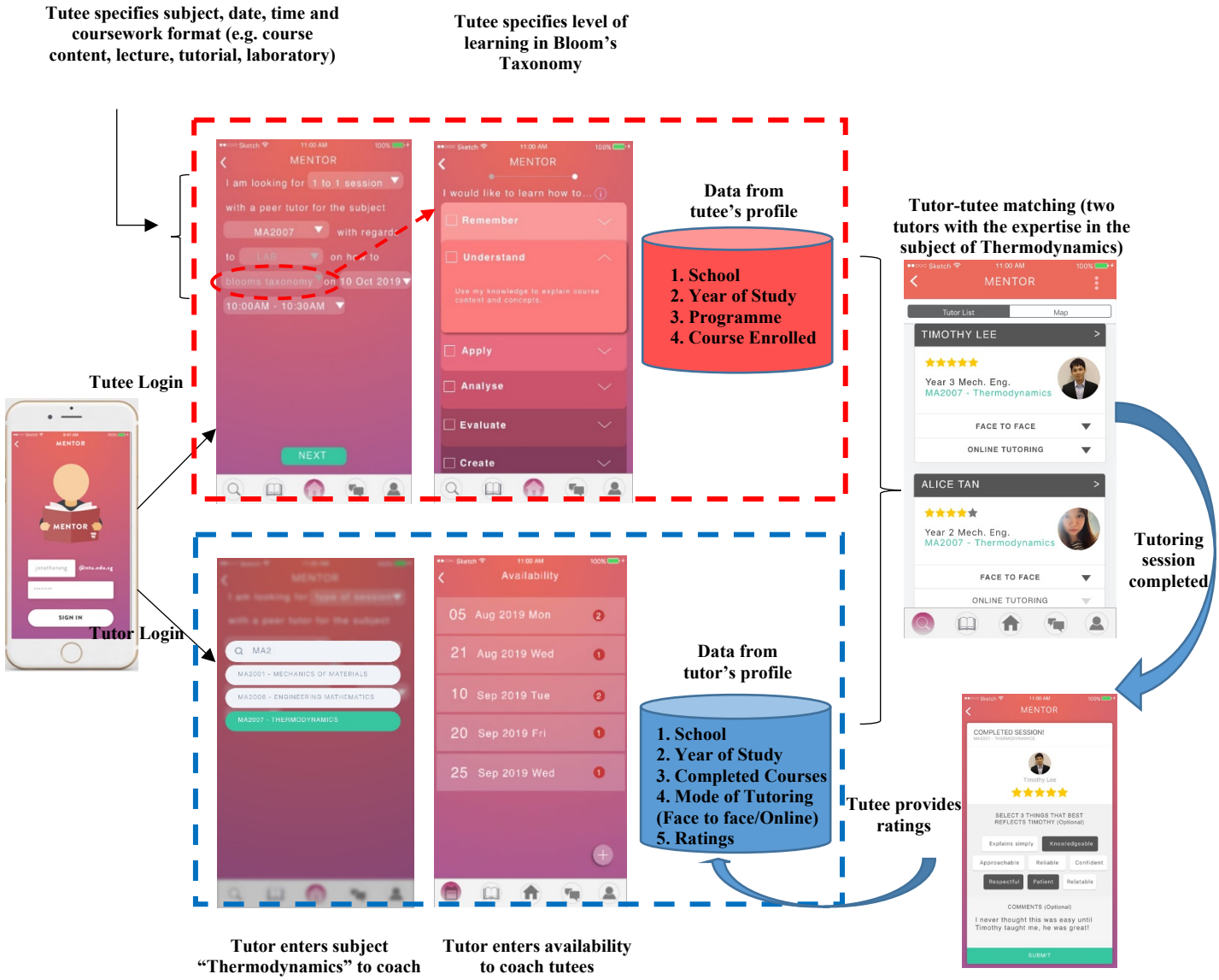


Figure 8. Implementation of Tutor/Tutee Predictive Modeling

At the next level, the use of specifying Bloom's Taxonomy levels of learning will help to define clear goals to assist MENTOR predictive model and understand the purpose of the tutee's problem. The use of Bloom's Taxonomy approximates the difficulty level and nature of the task or problem faced by tutees, as defined by the revised Bloom's level – Remember, Understand, Apply, Analyze, Evaluate, and Create (Anderson & Bloom, 2001).

The tutor-tutee matching provides pairing of tutees' requests for specific coursework tutoring with tutors who have relevant expertise in terms of coursework and discipline by using the parameters extracted from tutor/tutee profile as shown in Figure 8. The use of a predictive modeling approach for MENTOR application is based on the combination of algorithm parameters such as subjects, background, date and time, tutoring experience (completed courses, mode of tutoring) and tutor ratings.

Upon the completion of the tutoring session, the tutees who have experienced peer tutoring will provide ratings based on the tutoring session conducted by the respective tutor. The ability to have ratings and feedback is critical as one of the indicators to determine the listing of tutor-tutee matching and prescribe the right recommendation of tutors available for the subject of Thermodynamics (see Figure 8 for the two tutors recommended).

Online tutoring

In the MENTOR peer tutoring approach, online tutoring will be conducted in real-time communication that leverages collaborative learning space via an interactive screen sharing feature on a digital sketchpad interface. Figure 9 shows the virtual platform that enables tutor and tutee to create or view learning content created by themselves simultaneously. The learning content can also be uploaded to the sketchpad interface, and the users are able to add annotations during the online tutoring sessions. MENTOR interactive annotations approach is incorporated to foster interactions and collaborative learning among students. The shared virtual space provides a platform for both peer tutors and peer tutees to interact and exchange their views as shown in Figure 9. Besides, the tutor and tutee can communicate in the tutoring session through the real-time chat to clarify their doubts.

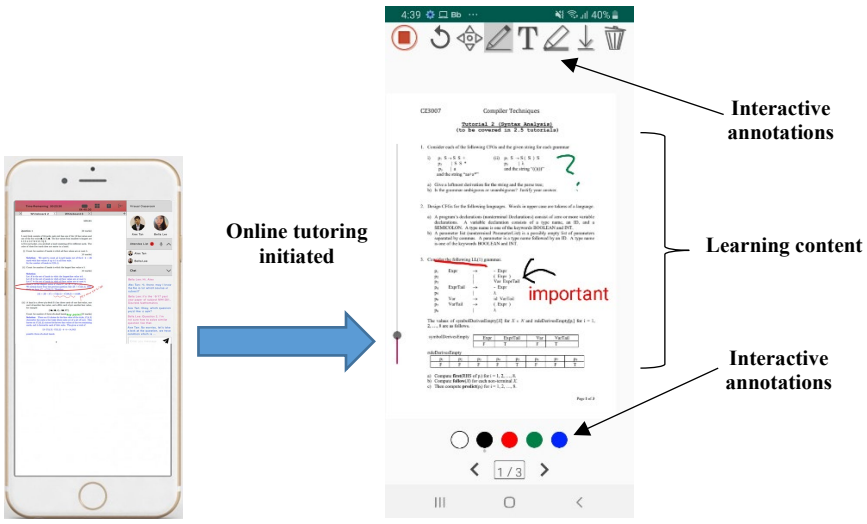


Figure 9. The use of online tutoring aims to provide a virtual platform as a tool for teaching, discussion using instant messaging, sketch mathematical formulas or equations in real-time.

Conclusion and Future Work

In this study, the holistic design of a novel smartphone app MENTOR with predictive analytics implementation is proposed to support peer to peer tutoring in a higher education institution. In the needs analysis, students have shown positive responses in the survey for the use of mobile applications in peer tutoring. The use of online peer tutoring with an interactive annotation tool helps the students to improve their understanding of the contents of the subject in real-time. Tutors are able to provide explanations and suggestions using the virtual space to enhance the student learning experience. The use of the learning analytics, data derived from tutor/tutee profile, and the tutor's and tutee's inputs underlie the settings of the tutor-tutee matching algorithm. Taking this further, the next step forward will be further investigation into the efficacy of mobile peer tutoring and analysis of the effectiveness of using student data and real-time information for predictive modeling. Analysis of the data such as ratings, the number of tutoring sessions conducted and the use of virtual space for online tutoring sessions are important and will be explored in greater depth to examine the functionality, effectiveness of the tutor-tutee matching algorithm and learning analytics implementation.

MENTOR approach can be extended to various educational institutions in designing an effective peer tutoring model and provides insights that can inform approaches for the development peer tutoring model using predictive modeling. Future work following this research will involve the implementation of MENTOR peer tutoring application and integration with existing university databases using a carefully designed adoption strategy.

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