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Chao-Hsiu Chen[a]; Gwo-Jen Hwang[b]; Tzu-Chi Yang[c]; Shih-Hsuan Chen[d]; Shen-Yu Huang[a]
[a] Institute of Education, National Chiao Tung University, Taiwan [b] Department of Information and Learning Technology, National University of Tainan, Taiwan [c] Department of Computer Science and Information Engineering, National Central University, Taiwan [d] HeimaVista Inc., Taiwan

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Analysis of a ubiquitous performance support system for teachers

Chao-Hsiu Chen[a], Gwo-Jen Hwang[b]*, Tzu-Chi Yang[c], Shih-Hsuan Chen[d] and Shen-Yu Huang[a]

[a]*Institute of Education, National Chiao Tung University, Taiwan;* [b]*Department of Information and Learning Technology, National University of Tainan, Taiwan;* [c]*Department of Computer Science and Information Engineering, National Central University, Taiwan;* [d]*HeimaVista Inc., Taiwan*

This paper describes a Ubiquitous Performance Support System for Teachers (UPSST) and its implementation model. Personal Digital Assistants (PDAs) were used as the platform to support high-school teachers. Based on concepts of Electronic Performance Support Systems and design-based research, the authors conducted an iterative process of analysis, design, development, and evaluation. Besides the data collected from the two initial users during the iterative process, 12 teachers were recruited for evaluating the functions and interface design of the UPSST. The participants mostly reported positive attitudes toward the functions and interface, but some expressed concerns. Explanations of the concerns and suggestions for future studies are provided.

Keywords: performance support system; mobile computing; high school education

Introduction

In the past decade, systems and learning theories have been developed for learning with computer and network technologies, while the effectiveness of these implementations has been empirically evaluated as well (Barrett & Lally, 1999). One major difficulty for teachers in utilising the new technologies is the lack of easy-to-use interfaces and easy-to-access support during the tutoring process. Chou (2003) indicated that teachers are the key to the successful use of the Internet for both teaching and learning. However, without any support, teachers' anxieties often reduce the success of such technological and pedagogical innovations. The concepts of Electronic Performance Support Systems (EPSSs) focus on providing task performers with necessary support and learning opportunities within working contexts so they can improve their performance and acquire relevant knowledge and skills while performing tasks (Barker, van Schaik, & Famakinwa, 2007; Cagiltay, 2006). Researchers have recommended integrating EPSS concepts into educational settings to enhance teaching and learning (e.g., Chiero, 1996; Peng, Chuang, & Hwang, 2007; van Schaik, Pearson, & Barker, 2002).

Most students in Asian countries do not move between classes, and they usually stay in their 'home classrooms' to learn most subjects. Most teachers go to home classrooms to teach according to schedule. In Taiwan, each class/homeroom (similar

*Corresponding author. Email: gjhwang@mail.nutn.edu.tw

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to a tutor group or form in the UK) is assigned a homeroom teacher. Often, the homeroom teachers are busy handling class management and administration work. Hence, we assume that a well-designed EPSS could not only reduce homeroom teachers' workloads, but could also facilitate class management for novice homeroom teachers.

Meanwhile, the characteristics of mobile technology such as ubiquity, smaller sizes, and comparatively cheaper prices, and the widespread use of wireless networks has encouraged researchers to further investigate the potential of integrating mobile technology with EPSS applications (Barker et al., 2007; McManus & Rossett, 2006; Peng et al., 2007). Although the idea of utilising mobile technology to support the performance of high-school teachers has been addressed and a prototype of a preliminary interface design has been developed (Peng et al., 2007; Chuang, 2007), there seems to be no comprehensive system with multiple support functions available for high-school teachers. Therefore, this current study proposes a model of Ubiquitous Performance Support System for Teachers (UPSST) and intends to plan, design, develop, and implement this application with ubiquitous technology to assist the performance of high-school teachers. Two high-school homeroom teachers were the initial users of the UPSST, and another 12 homeroom teachers participated in testing the developed system. Their opinions on the UPSST and its application were documented.

Theoretical framework

Electronic Performance Support Systems

Society nowadays emphasises the importance of lifelong learning and, in fact, most adults acquire their knowledge and skills mainly from their work after leaving school (Brown, 1996). Therefore, methods for helping adults to effectively learn relevant knowledge and skills during task execution have become an important issue, and the concept of Performance Support Systems (PSS) appears an attractive solution. The purpose of such systems is to improve task performance by providing performers with just-in-time support and information, meaning that the intervention is triggered whenever and wherever the user needs it. With the improvement of computer technology, Electronic Performance Support Systems (EPSSs) have been developed to assist workers to make their jobs more productive and efficient (Barker et al., 2007; Cagiltay, 2006).

Compared with traditional training, EPSSs allow users to learn and to perform tasks simultaneously, and therefore they are highly context-sensitive. Because the main purpose of an EPSS is to provide users with necessary information, guidance, and support in certain contexts, their design should adapt to the needs of different users and give users appropriate informative responses accordingly to support the users' learning and decision-making. In addition, EPSSs can support users' learning processes including reflection, articulation and abstraction (Wild, 2000). EPSSs can adapt to different situations, different stages of task execution, and different types of users and learners, and provide continual and flexible support and information. Besides traditional training of employees, EPSSs have also become an important option for fostering the knowledge and skills of employees in industries and organisations (Brown, 1996).

Researchers have noticed the potential of EPSSs for improving teaching and learning in school contexts. The idea of giving learners just-in-time feedback and guidance via EPSSs is consistent with the concept of scaffolding proposed by learning theorists

(Wood, Bruner, & Ross, 1976). With the scaffolding provided by an EPSS, learners gradually develop expertise in certain areas (Barker et al., 2007; Wild, 2000). Regarding the application of EPSSs in education, they can combine various technologies and resources to improve teachers' performance. Well-designed EPSSs can play different roles such as librarians, advisors, and instructors to provide users with instant, relevant, and useful information and advice, and all kinds of built-in tools can reduce teachers' work loads and information loads, and facilitate teachers' effectiveness (Chiero, 1996).

Meanwhile, ubiquitous (or mobile) technology and its applications have spawned an extensive programme of research because of the rapid growth in wireless sensor networks. The innovative technology can detect incidents in contexts and give users instant responses, information or support (Hwang, Tsai, & Yang, 2008). Employing ubiquitous technology in the design and implementation of EPSSs has potential to allow task performers more possibilities and flexibility in working contexts. Hence, research on how ubiquitous technology such as laptop computers and hand-held devices can influence the design and implementation of EPSSs and on how to generate more effective work-support models and applications deserves further investigation (McManus & Rossett, 2006). Likewise, teaching and learning are not restricted to classrooms and schools, and research investigating how to integrate ubiquitous technology with concepts of EPSSs inside and outside school environments should provide meaningful perspectives on how ubiquitous technology can contribute to effective teaching and learning (Barker et al., 2007; McManus & Rossett, 2006; Peng et al., 2007).

Using ubiquitous technology in educational settings

Due to the attractive features of hand-held computers such as portability, adaptability, flexibility, intuitiveness, and comparatively cheap prices, ubiquitous/mobile learning which integrates hand-held computers with wireless networks in teaching and learning has become one of the leading topics in educational research. Chan et al. (2006) argued that one-to-one hand-held computers will be an indispensable tool for many students in 10 years time, and that many countries can directly cross the digital divide via such technology because of the much lower cost. They envision more chances of collaboration on research projects related to mobile technology among researchers from different countries, and the formation of global research communities in this area.

Regarding the benefits of using ubiquitous/mobile technology in school teaching and learning, research results indicate teachers' positive attitudes toward this kind of technology use in education. For instance, SRI International implemented a project called Palm Education Pioneers in more than 100 K-12 schools to investigate how teachers and students used hand-held computers in various school contexts. Over 90% of the teachers held positive attitudes toward using hand-held computers in K-12 classrooms, and they reported positive influences of using hand-held computers on students' learning, such as more time spent by students in learning with technology, higher learning motivation and more communication and collaboration among peers. The teachers also reported easier and more frequent communication with parents via hand-held computers. For example, teachers would ask students to show parents requirements and information about homework, school calendars and activities, and students' behaviour in schools via hand-held computers. Consequently, parents were involved in school activities more often, and the rate of assignment completion

increased (Vahey & Crawford, 2001; 2002). The study by Becta (British Educational Communication and Technology Agency) on incorporating PDAs into school environments revealed similar positive results (Perry, 2003).

Chen, Yu, and Chang (2007) indicated that students' academic performance and social competence in school are strongly influenced by parents' participation in school activities because parents who are willing to communicate with teachers have a better understanding of students' learning and behaviour in school and tend to provide necessary support promptly. Chen et al. argued that most educational research on learning models pays too little attention to the factor of parents' influence, and so they designed a web-based E-Homebook system for the communication of teachers, students, and parents. The system contains students' learning portfolios, and teachers can observe and evaluate students' performance via this system. When detecting unusual performance in students' learning, the system will automatically send teachers and parents a warning email to suggest that they give the students the necessary assistance. The system also records information about parents' participation for teachers to consult in future communication with parents. However, it seems that there is limited research on a systematically-designed EPSS with ubiquitous technology to provide teachers with just-in-time, necessary, informative, and flexible support (Chuang, 2007).

Analytical framework

Methods and participants

The design and development of EPSSs is mostly based on concepts of cognitive psychology, instructional design, system design, and user-interface design (Brown, 1996; Chiero, 1996). Many ideas about design-based research which are derived from concepts of product design, instructional system design, innovation development, and educational research are consistent with the characteristics of EPSS design and development. Besides, design-based research emphasises the iterative cycle of formative evaluation (e.g., Barab & Squire, 2004; Collins, Joseph, & Bielaczyc, 2004; The Design-Based Research Collective, 2003). In this current study, we employed these concepts shared by EPSS design and design-based research to analyse, design, develop, implement, and evaluate the UPSST.

To fully understand the daily routines, special needs, and working environments of homeroom teachers, we invited two junior high-school homeroom teachers to participate in our study. We visited their school to observe and interview the two participants and other faculty and staff whose work was associated with that of the homeroom teachers. Based on data collected from the school visits, we designed, evaluated, and redesigned a prototype of the UPSST. After completing a beta version of the UPSST and coaching the two teachers in operating the system, we regularly visited them to follow their trial experiences and solicit their opinions about how to revise the system.

Regarding the homeroom teachers' attitudes toward the usability and application of the UPSST, we recruited an additional 12 homeroom teachers to test the system and fill out questionnaires to help us understand their agreement levels and opinions concerning the functions and user-interface design of the UPSST. Eight teachers agreed to be interviewed after filling out the questionnaires. The interviews were audiotaped and transcribed for data analysis. So far, the collected data were mostly qualitative, and we followed the coding strategies specified by Merriam (2001) to

code and categorise the qualitative data. After multiple times of adding, deleting, and revising categories, we confirmed the results, which are reported here.

The UPSST implementation model

Figure 1 presents the UPSST implementation model we proposed. The UPSST consists of three system modules, that is, the Data Exchange Group, the UPSS Service Group, and the User Interface Group. The Data Exchange Group is the module for maintaining the consistency of data in the databases of the UPSST and the official administrative systems. The data collected or modified by the teachers need to be uploaded via this module to ensure the security of the official database. The UPSS Service Group consists of the most frequently used functions for the daily work of high-school homeroom teachers, that is, 'calendar', 'student records', 'conduct-record management', and 'academic-record management'. The User Interface Group provides flexible interfaces and operation functions to assist the teachers in accessing and updating data via PDAs or personal computers; that is, the UPSST will display the same data with different presentation styles (e.g., brief or detailed information, low or high resolution) based on the devices used by the teachers.

Connecting to the existing administration automation system, the UPSST server automatically retrieves information and records scattered around different offices. For instance, the academic affairs office manages all students' academic records, the student affairs office helps homeroom teachers with issues related to students' behaviour, and the counselling office provides all kinds of counselling services. Teachers can use PDAs with the developed UPSST system to receive reminders or information they need for performing tasks. They can also update records stored in the server or

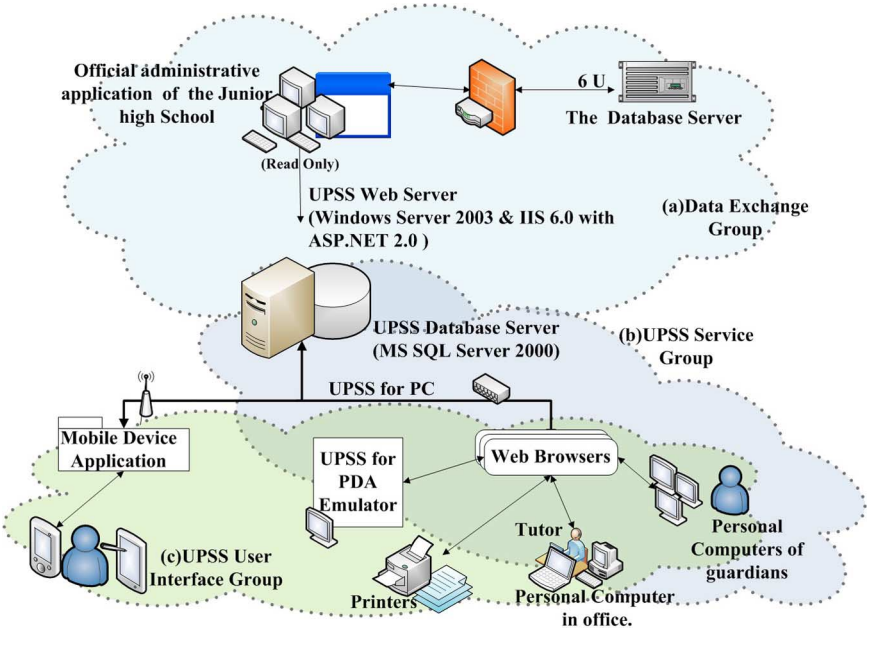

Figure 1. UPSST implementation model.

send requests to obtain necessary information via their PDAs. Through PDAs and the UPSST, teachers have easy access to the assistance and information they need for effectively communicating with parents, students, and colleagues. In addition, they can easily update existing records, append new records, or write down personal reflections regarding how to better tackle students' behaviour and improve students' performance. Teachers can also print out relevant information in formats consistent with the school's official forms.

To prevent important data in the administrative system from being modified by unauthorised persons, the physical database server of the administrative system is protected by a firewall, and a read-only copy that is refreshed periodically is accessed by the UPSST. An asynchronous strategy is also adopted by the UPSST for updating the data collected by the teachers.

Results

The UPSST Implementation

The server part of the UPSST was developed on the .NET Framework 2.0 platform with Microsoft Windows Server 2003 and Internet Information Service 6.0 (IIS) for web services and Microsoft SQL Server 2000 for database management. The application programmes were developed with Visual C# .NET. Figure 2 shows the system structure of the UPSST, which is connected to the official administrative applications of the junior high-school. Figure 2 shows the four basic functions for supporting the daily work of teachers using the PDA version of the UPSST, that is, calendar, student record, conduct-record management, and academic-record management.

The calendar function includes the events concerning teaching, class management, student counselling, school activities, and administration items. Teachers can manage the calendar by performing read events, update events, or add new events operations via the interfaces that display daily, weekly, or monthly records.

The student-record function allows teachers to access the personal information, counselling data, behaviour data, and academic data of individual students. Figure 3 shows the interface of the student-record function. In this illustrative example, a particular behaviour record of the student is displayed in Figure 3(a). After interviewing the student, the teacher records the counselling results such as treatment and the responses of the student via the interface depicted in Figure 3(b).

The conduct-record management function is used to manage the attendance records, cleaning duty performance, and special behaviour/performance records, which are stored as part of the behaviour data. A report that summarises these records will be generated as a reminder when a teacher logs into the UPSST. Figure 4 shows an illustrative example of the conduct-record management function. In Figure 4(a), the teacher records the special behaviour of a student, including late for class and bad performance of cleaning duty. A report concerning such special behaviours will be generated and displayed as a reminder when the teacher logs into the UPSST later.

In Figure 4(b), the academic-record management function is used to maintain the performance of students in terms of academic performance, class management, student counselling, school activities, and administration items. In addition, the teacher can query the list of students who fail to pass the tests within a particular week. In addition, the UPSST provides a performance analysis function to analyse the academic performance for individual students, so that the teacher can compare the learning status of a certain student with that of other classmates. Figure 5 shows the PDA interface

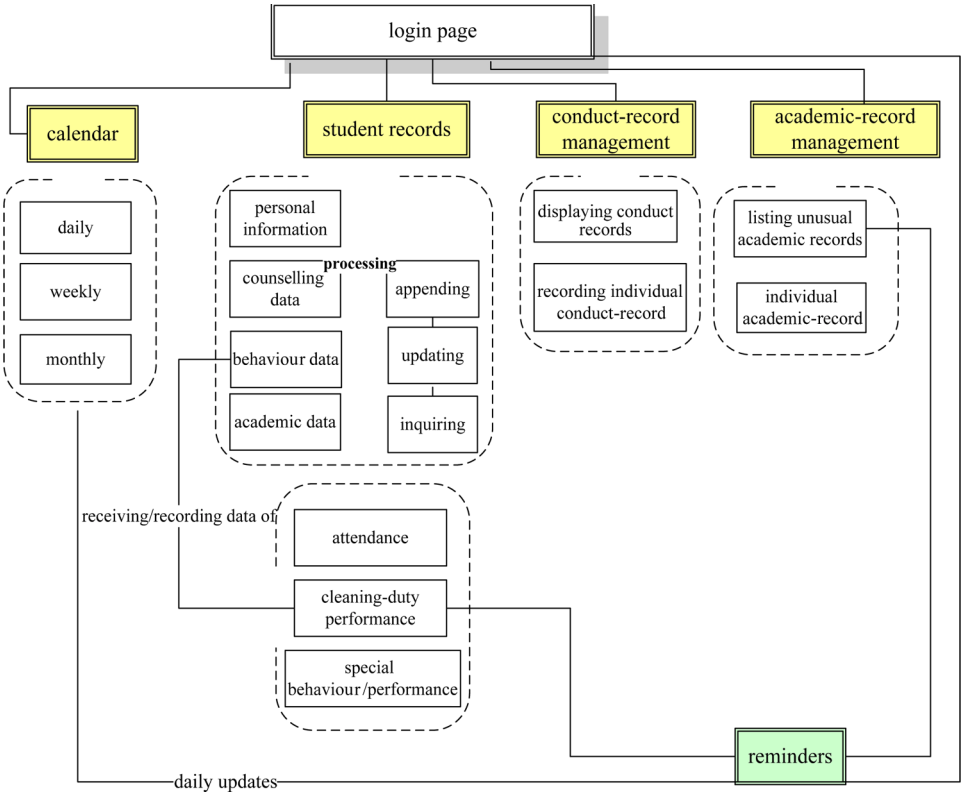

Figure 2. Functions for teachers in the PDA version of the UPSST.

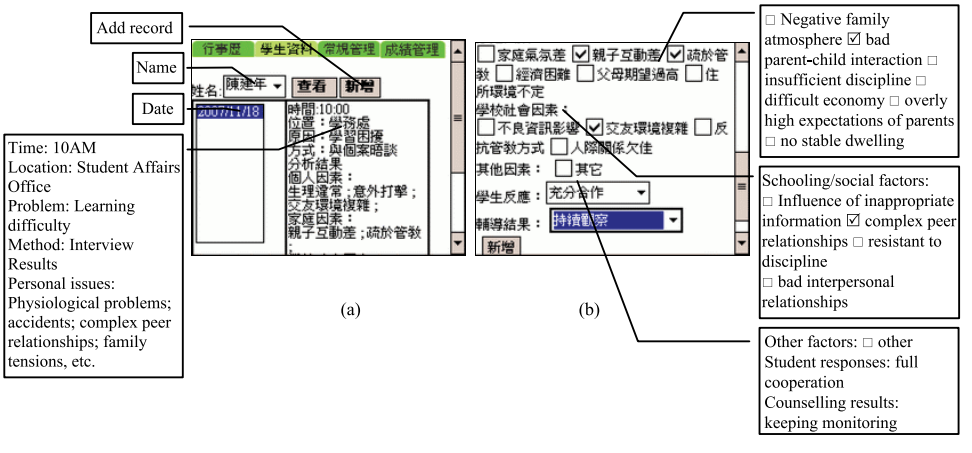

Figure 3. Interface of the 'student record' function.

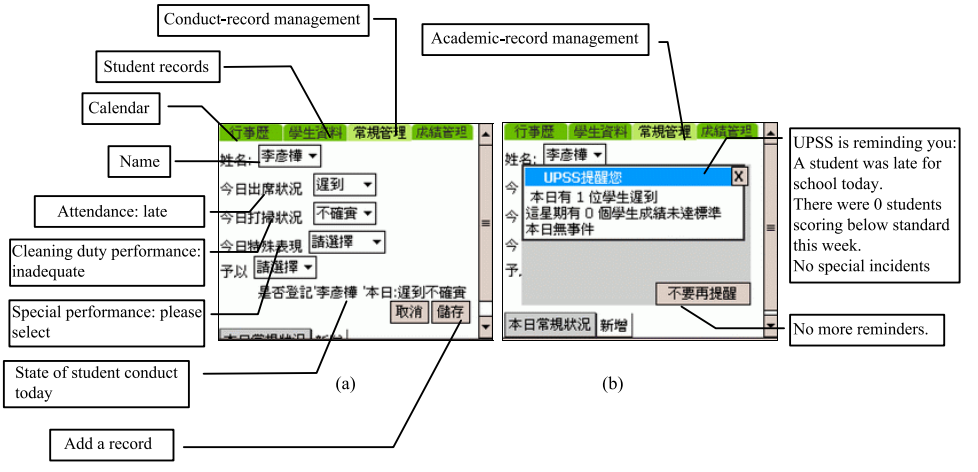

Figure 4. Illustrative example of the 'conduct-record management' function.

of the academic-record management function. In Figure 5(a), the UPSST displays the test scores of a student. The performance analysis result of the mathematics test for the student is shown in Figure 5(b), comparing the test score with those of other students in the class.

System evaluation

After completing the beta version of the UPSST, we invited 12 homeroom teachers to test it. The 12 teachers filled out questionnaires including closed- and open-ended questions after the trial, and we interviewed eight of them to allow us to further understand their opinions of the functions and interface design of the UPSST and its utilisation in school. Table 1 lists the percentages of the 12 teachers' responses to the closed-ended statements. The first nine statements are related to functions provided in the UPSST, and the remaining items are to understand respondents' perceptions of the interface design. Although the 12 teachers mostly reported the usefulness of receiving and managing information via the UPSST, not all participants considered the UPSST

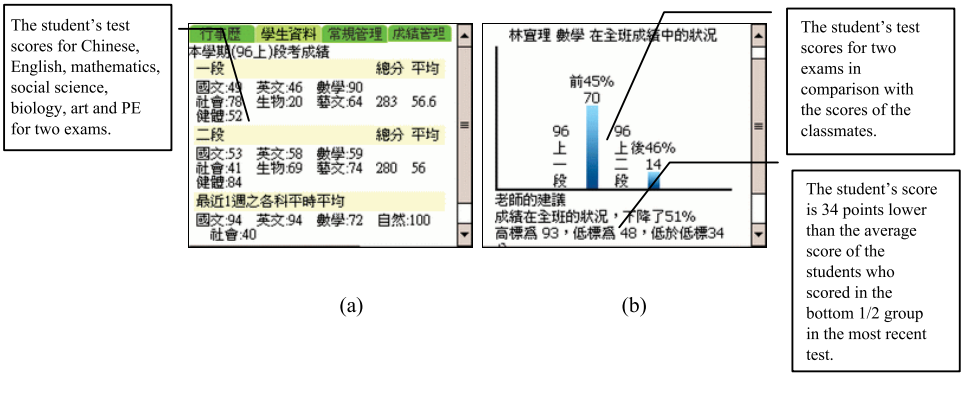

Figure 5. Illustrative example of the 'academic-record management' function.

an effective solution to communicating with parents and to reducing their workloads. Their answers to the open-ended questions and interview data provided possible explanations of their concerns.

The teachers' answers to the open-ended questions confirmed the benefits of the UPSST such as its ubiquity, convenience, readiness, timeliness, and richness in

Table 1. Percentages of 12 homeroom teachers' agreement levels on the survey items.

Item statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Strongly agree
1. The schedule function is useful for time management.	0.00%	8.33%	16.67%	41.67%	33.33%	75.00%
2. The UPSST can help teachers detect students' unusual academic performance.	0.00%	8.33%	16.67%	50.00%	25.00%	75.00%
3. With the UPSST, teachers can better understand students' behaviour in school.	0.00%	8.33%	0.00%	41.67%	50.00%	91.67%
4. The graphic representations in the UPSST are helpful for comprehending data instantly.	0.00%	8.33%	0.00%	41.67%	50.00%	91.67%
5. The UPSST is valuable for managing the data of student counselling.	8.33%	0.00%	0.00%	58.33%	33.33%	91.67%
6. The UPSST facilitates the communication with parents.	0.00%	8.33%	41.67%	41.67%	8.33%	50.00%
7. The UPSST can help novice or practicing teachers become experienced more quickly.	0.00%	8.33%	16.67%	41.67%	33.33%	75.00%
8. The function of sending reminders can reduce information loads.	8.33%	8.33%	16.67%	41.67%	25.00%	66.67%
9. Overall, the UPSST can improve the performance of homeroom teachers.	9.09%	0.00%	27.27%	45.45%	18.18%	63.64%
10. The graphic and text representations are consistent.	0.00%	8.33%	25.00%	33.33%	33.33%	66.67%
11. I can easily find the function I need.	8.33%	0.00%	33.33%	41.67%	16.67%	58.33%
12. It is easy to navigate between pages.	0.00%	8.33%	8.33%	50.00%	33.33%	83.33%
13. The screen layout is intuitive.	0.00%	9.09%	27.27%	45.45%	18.18%	63.64%
14. The messages are simple and clear.	0.00%	8.33%	0.00%	58.33%	33.33%	91.67%
15. Overall, the UPSST is easy to operate.	8.33%	0.00%	0.00%	66.67%	25.00%	91.67%

inquiring, recording, and managing information. The teachers envisioned benefits including easier grasp of students' behaviour and academic performance, more effective communication with parents, efficient use and management of electronic data, and substantial support for novice teachers. However, two respondents thought the functions could not fully meet their needs, possibly because we tailored the UPSST design for the two initial users rather than for the 12 teachers. Besides, some responses reminded us of the difficulty of introducing an innovative technology into school settings, especially when existing practices work well. Three teachers reported that the administration automation system, phones, and paper and pencil were good and fast enough for them to manage students' data and communicate with parents. The concerns expressed by the 12 teachers about the implementation of UPSST focused on the time and effort needed to learn how to operate a PDA and the UPSST, the availability of necessary equipment and technical support, the stability of the wireless network and server, and the compatibility of the UPSST with the current system. Although nine out of the 12 questionnaire respondents expressed their willingness to try the UPSST in their schools, without stable and compatible equipment and support, the benefits of the UPSST could not persuade the teachers to replace their familiar ways of performing duties with the functions provided in the UPSST.

We also found that while recognising the overall usability of the UPSST interface design, not all participants could intuitively navigate the system. The following open-ended questions and interviews provided useful information to further improve the interface design. However, we found that some of their less positive responses might result from their unfamiliarity with operating a PDA. Six out of the eight interviewees mentioned that a potential obstacle to implementing the UPSST could be teachers' resistance to operating an unfamiliar system, and the constraints of PDAs. Small screens and inconvenient data entry were mentioned as discouraging factors for teachers to adopt the UPSST in their daily work. Six respondents suggested we add functions which were already provided in the UPSST, possibly because the introduction to the trial and the trial itself had been too brief. Therefore, to conduct a thorough usability evaluation of the PDA's, user-interface, we should allow evaluators sufficient time to be familiar with PDA operation and the system to become tested. In addition, the UPSST design was based on the needs of two initial users, and the functions and interface design might not meet the needs of the 12 teachers and their working situations. Their suggestions for revision focused on how flexible it was to add more items and functions depending on teachers' additional needs, and on how to make the formats of output documents consistent with current paper and electronic documents used in their schools. These two areas of development are valuable recommendations for us to revise the UPSST for possible implementation in different school contexts.

Discussion and conclusion

This article presents the ubiquitous performance support system (UPSST) and its implementation model that we developed for Taiwanese high-school teachers to improve their performance. Combining concepts of EPSSs with the characteristics of ubiquitous computing, we established a system to provide teachers with instant and just-in-time support and information. We adopted an iterative cycle of stages including analysis, design, development, and evaluation, which is promoted by researchers of EPSSs and design-based research.

The 12 trial users confirmed the many advantages of utilising the UPSST in assisting their work, and they mostly showed positive attitudes toward the functions and interface design of the UPSST. However, not all participants agreed on the necessity of every function of the UPSST. Because the development of EPSSs and design-based research both emphasise the importance of fulfilling specific user-needs and taking contexts into account, we tailored the UPSST design to suit the initial-users' needs, their school settings, and their working contexts. It is not an easy task to maintain the balance between making the UPSST design meet the needs of specific users and contexts and allowing other prospective users enough flexibility to alter the functions and interface of the UPSST to fit their needs. The limitations of mobile computing devices such as small screen sizes and inconvenient input and output methods (Heath et al., 2005; Shin, Norris, & Soloway, 2007) indeed make our design even more challenging. Many researchers will keep facing the issue of how to keep screen layouts and operations simple and easy, and at the same time versatile and flexible enough to meet the needs of different users. The responses of the 12 trial users also reminded us of the complexity of implementing a technological innovation in an educational setting. They expressed concerns about the time and effort needed to become familiar with the PDA and UPSST operation, the shortage of necessary equipment, technical support, stable network connectivity, and, most important, the compatibility of the UPSST with their current practices and systems.

Although recruiting prospective users to test the UPSST did provide us with different perspectives from the initial users, we suggest that researchers also recruit teachers from the initial-users' school. Participants from the same school are more familiar with the school settings, work routines, and task contexts, so we speculated that such participants would have more common needs and give more concrete and detailed revision. From the experience of conducting our formative evaluation, we were reminded of the necessity of giving trial users enough time to digest the introduction to the UPSST, to raise questions, and to become familiar with the operation of the PDA system. Because most participants were not familiar with the devices, they could not totally attend to the functions and interface design to focus on the evaluation task.

Regarding future studies, we plan to undertake intensive field trials in the initial users' school, and to keep revising the UPSST, and we will continue collecting data to investigate how integrating ubiquitous technology into school settings differs from other forms of technology integration in education, and what factors influence the effectiveness of such integration. How teachers change their adoption of ubiquitous technology at different stages, and how their beliefs and practices change can be important research issues, and these studies can provide researchers and practitioners with insights into how to disseminate ubiquitous technology in meaningful ways.

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Notes on contributors

Chao-Hsiu Chen is currently an assistant professor at the Institute of Education at National Chiao Tung University in Taiwan. Her research interests include web-based learning, mobile learning, and technology integration in educational settings.

Gwo-Jen Hwang is currently a professor at the Department of Information and Learning Technology at National University of Tainan in Taiwan. His research interests include computer-assisted learning, computer-assisted testing and ubiquitous learning.

Tzu-Chi Yang is a graduate student of the Information Management Department at National Chi Nan University in Taiwan. His research interests include ubiquitous learning and knowledge-based systems.

Shih-Hsuan Chen is a marketing planning manager of an Internet company, HeimaVista Inc. Her research interests include web-based learning, mobile learning, and instructional system design.

Shen-Yu Huang is a graduate student of the Institute of Education at National Chiao Tung University in Taiwan. His research interests include web-based learning, mobile learning and instructional system design.

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