
Title	Bridging design and practice: Towards a model-based collaborative inquiry science learning environment
Authors	Daner Sun, Chee-Kit Looi and Baohui Zhang
Source	<i>10th International Conference of the Learning Sciences (ICLS) 2012, Sydney, Australia, 2 -6 July, 2012</i>
Published by	International Society of the Learning Sciences

This document may be used for private study or research purpose only. This document or any part of it may not be duplicated and/or distributed without permission of the copyright owner.

The Singapore Copyright Act applies to the use of this document.

Original citation: Sun, D., Looi, C.-K., & Zhang, B. (2012). Bridging design and practice: Towards a model-based collaborative inquiry science learning environment. In J. van Aalst, K. Thompson, M. J. Jacobson & P. Reimann (Eds.), *Proceedings of the International Conference of the Learning Sciences (ICLS) 2012* (Part 2, pp. 212-216). Sydney, Australia: International Society of the Learning Sciences.

Copyright 2012 International Society of the Learning Sciences

Archived with permission from the copyright owner.

Bridging Design and Practice: Towards a Model-based Collaborative Inquiry Science Learning Environment

¹Daner Sun, ²Chee-Kit Looi, Learning Sciences Laboratory, National Institute of Education, Singapore

³Baohui Zhang, Institute of Education, Nanjing University, China

1. daner.sun@nie.edu.sg, 2. cheekit.looi@nie.edu.sg, 3. baohui.zhang@nju.edu.cn

Abstract: The WiMVT system is a web-based science learning environment for secondary school students. In this paper, we describe the theoretical underpinnings that guided the design of WiMVT framework, the components and core features as well as the work flow of WiMVT. We elucidate our development process that supports the development of the system. To examine the functional usability and evaluate its impact on students' learning, a pilot study was conducted to show the findings with implications for how to improve the functionalities of the existing, briefly present the learning outcomes of lessons with the system, and provide feedback to the researchers, designers and teachers.

Keywords: WiMVT; science learning; inquiry

Background

Learning science through inquiry that incorporates Information and Communication Technologies and scientific practices has been a desired pedagogical approach for science learning. In recent years, a number of computer-supported inquiry-based science learning environments have been developed, studied and evaluated, such as WISE, Co-Lab, Inquiry Island, and nQuire. Substantial evidence reported such learning environments could facilitate the development of cognitive and metacognitive strategies in the pupils (Schwarz & White, 2005). Due to benefits for learners and the educational demand for a new science learning environment to effectively support the class and meeting the societal demands on science education, a group of researchers at Learning Sciences Laboratory, National Institute of Education in Singapore endeavours to develop a web-based science learning environment named WiMVT system (**W**eb-based **i**nquirer with **M**odelling and **V**isualization **T**echnology, <http://www.sstsl-wimvt.sg/wimvt/>). It is designed as an innovative learning environment in which modelling and visualization, inquiry and social interaction brought together and integrated. With a number of features, the system is targeted to support secondary school students to acquire sophisticated understanding of scientific conceptions, develop crucial learning skills (inquiry skills, modelling skills, collaborative learning skills) and reasoning skills, as well as reflective thinking skills. We will present a pilot study of WiMVT system, which happened at the stage of the development of simplified version. It is hoped this study could contribute to narrowing the gap between the design and development of a science learning environment and its actual usage and enactment in the classroom practice.

Theoretical Underpinnings

The pedagogical principles in model-based inquiry serve as the guide for design decisions on the framework of the WiMVT system. Different teaching patterns were formed and demonstrated in relevant studies. White and Frederiksen (2002) proposed an inquiry cycle that consisted of "question-predict-experiment-mode-apply". The results indicated that both of lower and higher achieving students benefit from this inquiry model. The inquiry phases in the Inquiry Island were described with questions, hypothesis, plan, investigation, creation and evaluation of models, and the evaluation of models and research processes. It was proposed to facilitate students' sociocognitive and metacognitive development (White, et al., 2002). Christina and Gwekwerer (2007) designed an inquiry framework EIMA: Engage-Investigate-Model-Apply. This inquiry pattern encouraged students' engaging in the guided inquiry with a focus on creating, using and revising models. In summary, despite of using different teaching patterns, these studies pointed to the necessity of having modelling as an important component in science inquiry. And the model-based inquiry process could mainly include orientation or question, hypothesis, plan, investigation, model, and conclusion (Bell, et al., 2010). With modelling as one of major strategies to visualize and examine students' conceptual understanding in science class, and guided by the relevant design and the educational principle: Predict-Observe-Explain (POE) adopted in science class in some Singapore schools (White & Gunstone, 1992), as it has been demonstrated as an effective way to examine students' prior knowledge and conceptual changes. Thus, we propose a phase named Pre-model with corresponding Model in the inquiry cycle to probe students' conceptual transformation process. Finally, based on the theoretical analysis discussed above, considering other prominent learning environments' design, a revised model-based inquiry cycle proceeded with eight phases is proposed: Contextualize, Question & Hypothesize (Q&H), Pre-model, Plan, Investigate, Model, Reflect, and Apply. These eight phases are refined as the components of the WiMVT inquiry cycle. Icons were used to denote each phase of the inquiry cycle in the system.

The Architecture and work flow of the WIMVT System

The WiMVT system operates via the Internet and is accessible through a general web browser. The system supports access of administrators, teachers, and students. The main functionalities of each component in the teacher and students module are as follows: 1) profile/mailbox: both of teachers and students are provided profile and mailbox. Profile is used to identify users based on photos, name, nationality and profile description; mailbox is designed to send message to exchange ideas, written materials or other information. 2) teachers' subject management: it allows defining subjects and grades for projects. 3) teachers' project management: it allows editing content, attaching guided questions, inserting images, videos and simulations, and establishing and managing groups for students. 4) teachers' solution review: it allows viewing and examining students' artefacts (e.g. written information, pre-models and models); providing feedback through a comment box. 5) teachers' simulation library: it allows uploading and executing simulations. 6) students' project: it allows students to go through inquiry phases to conduct learning activities and complete series of learning tasks. 7) students' group: it enables students to manage the access to the system and create or find an available group to join.

Based on the above functional module, the work flow of WiMVT system can mainly be executed in four stages: 1) the teacher establishes the project: the main tasks involve editing the Home page to give brief description, learning objectives, and tasks of the project (Linn, 2000); defining content of the Contextualize tab. Besides, the teacher is also responsible for assigning inquiry questions, plan, modelling tasks, the reflective task and assignments for students in terms of the inquiry levels. At last, the teacher arranges students' groups in appropriate size in the Group Management. 2) students get into the system: after logging into the system with their accounts and passwords, students can access to a work section consisted of four components aforementioned. Thus, general information of the assigned project can be viewed in My Project. 3) students conduct inquiry activities: students choose the project and access to the work session with their group members concurrently. The window of project work session generally consists of four panes: shared workspace (It holds the content or tools associated with each phase, status of group members, name list of group members, and a chat box. Students will experience a series of learning activities based on the available inquiry phases designed by the teacher. 4) the teacher reviews and comments artefacts: the teacher can access to students' artefacts (hypothesis, plan, investigation report and reflection content, pre-models and models, as well as Apply content) to review and comment them while travelling in the Review Solution section.

Core Features of the WiMVT System

The system encompasses three kinds of self-developed modelling tools: sketch tool, qualitative modelling tool and quantitative modelling tool. The sketch tool integrated in the Pre-model and Model tab respectively holds basic painting functions. The graphic-based diagram is employed to construct the qualitative and quantitative models in the Model tab. The quantitative modelling tool is building quantitative models via identifying precise mathematical formulas involving variables. A simulation engine is run when the relation has been specified in the form: 'If A goes up, B goes up' when students construct qualitative models. In this way, student-centred modelling thereby can be progressive because they can start from more qualitative models without having to define mathematical formulas and then get into the stage of more quantitative modelling when figuring out the mathematical formulas finally.

In addition to sketched models, diagrams of qualitative and quantitative models aforementioned, other representations are allowed to import in the system as the form of images and simulations. For example, interactive simulations can be embedded together with guided questions in the Investigate tab. The hyperlink of images, audio, videos can be established in the tabs as well. The use of multiple external representations is intended to receive motivational benefit but also leads the learner to a deeper understanding of the subject being taught (Ainsworth, 1999).

In the system, the noted feature is the shared workspace combined with a chat window embedded in several inquiry phases. The design supports students' synchronous (real-time) co-constructive modelling, as well as peer discussions. More specifically, the shared modelling space encourages students to work jointly to create something complex models which are impossible to construct individually (Urhahnea, et al., 2010). On the other hand, the interactive collaboration between teachers and students are established by asynchronous review function, comment box and mailbox. In that way, students are quite possible to look back and revise their pre-models after they receive the quick feedback through the comment box.

Development Process of WiMVT System

The development process consists of five short cycles which mostly involve: design → discussion → selected features development → discussion & usability test → redesign and improvement. At each development stage, weekly meetings involving designers, programmers, researchers and teachers are conducted for discussing design decisions, lesson plans, lesson design and research plans, etc. For the system evaluation, our actual pathway involves getting feedback and comments from consultants and collaborators from different research disciplines, such as science education, computer technology, and educational technology. Four levels of studies have been done or to be done in the development process. Level 1 (the usability tests in Cycles 1 and 2) is focused on improving the functionality of the system through standard usability heuristics and groupware

heuristics. Level 2 (the usability tests in cycles 1 and 2 we called them pilot studies in this paper) uses classroom-based studies to find evidence that can inform how the software and pedagogical activities can be modified and improved. Level 3 (the educational research in cycle 3) refers to a longitudinal study of our dependent variables (conceptual changes, inquiry skills, reasoning skills and modelling skills) when the system is fully prepared (Luckley, et al., 2003). Much further studies which address what supports are necessary to support the adoption and adaptation of the system in science lessons will be conducted in terms of the data analysis of educational research and feedback. To date, we have completed usability tests in research cycles 2 and 3. In this study, we focus on the findings from the first pilot study of the simplified version in cycle 1 which seek to identify problems in enacting inquiry-based learning activities with the iMOT system in the classroom, so that continuous improvements on design and pedagogy can be made.

Pilot Study on WiMVT Simplified Version

Participants

In this study, 20 students from two secondary 2 classes and 5 physics teachers with around 9-year teaching experience from a school in Singapore were participated. As a future school, the school had excellent computer facilities and employed full-time ICT coordinators who assisted teachers in the technical aspects of the use of ICT in their teaching. ICT skill was one of the key learning objectives listed in the school's syllabus. Each student owned and used Macbook for daily lessons in the various subjects.

Processes

The study consisted of two phases, namely, the co-design of the iMOT lessons and the iMOT instruction. In the co-design process, 5 science teachers contributed to the design of instructional contents, researchers and collaborators helped to revise and refine teachers' instructional design. Designers and programmers focused on the usability of the system. The classes studied the topic of "Current Electricity and D.C. Circuit" for around two weeks. The main objectives were that students should be aware of 1) the definitions of current and current flow 2) the relationship between current, voltage and resistance 3) the scientific models of analysing current 4) resistance in simple series and parallel circuits 5) modelling skills of creating simple circuits. The topic was divided into 10 lessons of 10 minutes each. Four lessons incorporated the use of the iMOT system. Before class, students tried the system at home to familiarise its functions. As 20 students in each class were divided into 4 groups with heterogeneous, they mainly worked in triads.

Data Source and Data Analysis

The study was aim to examine the relative technological functionalities and their impact on students' learning activities. Multiple sources included field notes, observation sheets, screen capture videos, face-to face interviews, onsite videos and audios, learning artefacts were selected for data collections. We used software to capture each screen activity to validate the data analysis. Videotaped recordings of the teacher and students' interactions at different points in time, in both whole and small group settings, were used to identify patterns of change for triangulation purposes. One audio recorder was directed at each of 4 groups in both of classes. In the data analysis, all videotapes and audios were transcribed to examine the usability violations and students' learning performance on the involvement of learning activities. The results were subsequently verified by cross-referencing collected data. On the other side, we used Audiodata to manage and analyse data from classroom observation and the teacher and students' interview to get feedback on both of usability and instruction. The combination of the qualitative and quantitative analysis method was proposed to reveal the relationship between existing technological functionalities and the learning activities.

Findings and Discussions

Usability in Learning Activities

We recorded and analysed students' main usability violations which referred to the obvious usability problems in learning activities. In this study, the diagnosis of the main violations was based on observing students' performance of using the system. This was done to detect the system bugs, and lagging issues. The findings helped us to make design decisions on the supplementary functions, as well as inform the improvement of relevant teaching strategies. Figure 1 depicts the rate of the major usability violations in the class. The rate of violations referred to the rate of students who had the same challenges. For the Contextualize tab, 20% of students just glanced over this content. We inferred that the textual information without any images offered little attraction. In the pre-model, students' misoperation of the toolbar and inadequate cooperation lead to the high rate of incomplete tasks. In the Model tab, the same problems still existed but receiving low rate, because of more guidance of the cooperation in modelling phase was offered by the teacher. According to the observation, some of students just wasted some time to walk around other tabs. On the other side, more attention should be paid on teachers' teaching skills of the iMOT implementation. Therefore, the proposed design decisions as well as the recommendation on the teaching strategies were refined as follows: 1) design decisions: lock function for tabs that are not required for the particular lesson; improve "free hand" function of sketch tool to decrease the bandwidth requirement 2) a reminder for "Clear" the team's artefacts 3) popup of tool description when mouse over 4) move save button at the bottom of the workspace 5) enlarge the modelling space using scroll bar

reminder message for saving when logging out. 2) teaching strategies: guide students' collaboration □ integrate appropriate representations into Contextualize □ show exemplar models for students □ guide and monitor students' modelling process □ provide appropriate feedback □ teaching cooperative skills.

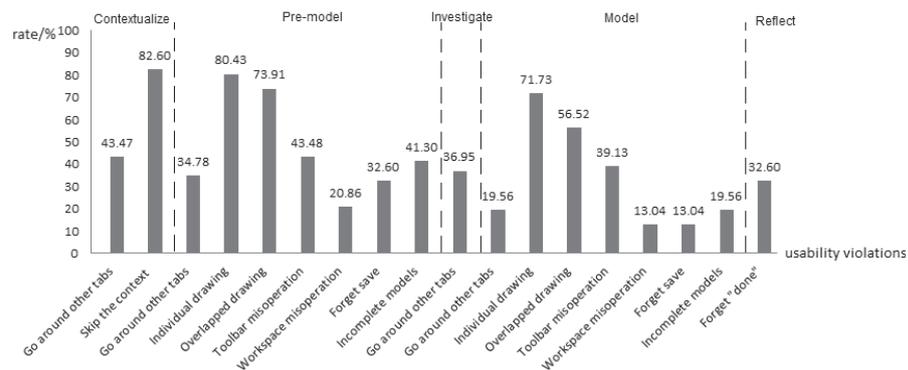


Figure 1. The rate of usability problems in each phase

Students' Modelling Performance

In this study, the modelling task was building a model of circuit which used in qui □ show for □ teams of participants, and pointing out the direction of the current flow in the Pre-model phase and revising the pre-models in the Model phase. □eflection was then proposed to help students gain further insight into their experience and understanding of the relevant knowledge in □eflect tab. In this paper, the quality of models was used to assess students' modelling performance, because the changes of quality of models suggested the changes of students' modelling performance. □e classified the quality of models into three levels (□rosslight, et al., 1991 □ □arrison □ Treagust, 2000): 1) □igh □uality Models (□□Ms) which contain accurate description of science conceptions or phenomena that involve objects with basic properties, and reflect interaction between objects. 2) Medium □uality Models (M□Ms) are the models featuring partially exact description of particular scientific conceptions or phenomena and they take into account some of appropriate components of models. The representations of M□Ms are generally at the concrete level. □) Low □uality Models (L□Ms) refer to the models which contain inaccurate description of all modelling components, they are usually at the level of the scribble drawing. □elow are the exemplar models of circuits at different quality levels drawn by students in this pilot study, see Figure 2. In this study, we collected a total of 11 models in Pre-model phase, and 1 □models in Model phase. The results showed that the M□Ms occupied most in both Pre-model and Model phase with the rate of □2 □ and □1 □. For M□Ms in Pre-model phase, most of them were constructed without defining the current flow directions. And compared to □groups of students drew the wrong current flow directions, only one group made the same mistake in the Model phase. In the Model phase, □groups defined the right objects of models □however, they drew the current in the broken circuits. Additionally, the increment of the □□Ms in the Model phase reflected students' understanding of circuits had improved significantly. Moreover, there was no L□M in the Model phase. In conclusion, students performed better in the Model phase with less usability violations (see Figure 1) and better quality of models. □tudents' positive responses on the process of understanding the circuit and current in □eflect phase were demonstrated their progressions, such as:

I used to think that short circuits are very complicated, but they are not. In addition, I thought that parallel circuits have different current for each bulb. □ut now, I think that for parallel circuits, the bulbs have the same brightness as the same amount of current is being flowed through it. Only, when the switch is closed, then the electrons can starts flowing. □ulbs in series circuits have lower brightness than bulbs in parallel connection.

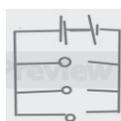


Figure 2a. L□M

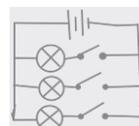


Figure 2b. M□M

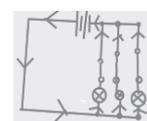


Figure 2c. □□M

Voices of the Teacher and Students

The transcribed interviews were analysed with a view to get feedback on the improvement of the system based on the learning practice. The interview focused on their opinions of the whole system, design features and its implementation in learning activities. In brief, the teacher and students expressed an overall positive attitude towards the □iM□T and their perspectives on the further design and development. □ased on the transcript matrixes of the □udiocode data analysis on the interview, we concluded that the teacher provided more suggestions on the functionalities based on her observation of students' interaction with the system. □e summarized her main comments as follows:

1) □he had a better understanding of the lessons which could be designed to leverage on the affordances for the □iM□T cycle: Lesson plans should be adopted for best fit with the □iM□T inquiry cycle □it was proposed that a few appropriate tabs were to be used at each time in normal lessons □individual modelling approach was more suitable for some lessons compared to collaborative modelling approach.

2) He suggested some supplementary design of the system: In Pre-model and Model phases, students were allowed to draw models on a more extensive modelling space to control the learning process, the unused tabs would be locked in the current lesson, the locked tabs would be released when it was unused in the subsequent lessons. Lesson folders could be established after students finished their learning activities for a particular topic or chapter, the folders could be printed and saved as documents for recording students' learning performance. Meanwhile, students' participation could be traced within the iMOT system.

Most of students provided their comments on the functionalities and the design, as well as the learning activities with the system. The below comments are concluded by their major comments:

1) Most of students thought the learning activities with the system were more interesting and engaging compared what they had used previously. Students who had the similar prior experience pointed out that the small group's collaboration provided more opportunities to do experiments or other activities in iMOT system. Students appreciated the synchronised collaborative work, which they thought the work would be finished with a faster space and it benefited their science learning. The synchronised modelling process allowed more than one person to draw the model at one time. It did help them to spot mistakes from each other and learn from that mistake within a student work group. And they thought they enhanced their understanding of electrical circuits bring taught in the lesson through the comparison of pre-models and models, as well as a reflection phase to concretise the thinking process.

2) On the aspect of system design, students mentioned the navigation of the system was simple, easy to learn, and user friendly. However, some of them thought judicious use of colour coding in the iMOT interface may enhance the user-friendliness and presentation of the interface. For the chat function, some of students commented that embedding a voice communication channel would complement the chat function, as students may find it harder to write down their thinking process in some situations. It was hoped that the stability of the system could be improved greatly by the next iteration.

Conclusions and Further Work

In this paper, we propose a revised inquiry cycle as the framework of iMOT system, describe the components and the core features of the system, as well as interpret the work flow of iMOT instruction. Intend to establish a benchmark of the type of research and development for the comprehensive learning environment, we then describe the development process of the system. With the aim to evaluate and improve the existing system, a pilot study was conducted to examine the usability and learning practices with iMOT system. The findings from this pilot study indicated the value of the system for science learning, as well as provided confirmation of further design and development in later versions. In doing so, we hope to narrow the gap between the intended design and its use in a real learning context. At present, the system allows inquiry to be done by using the simplified version. The remaining learning management features that further facilitate collaborative model-based inquiry are still under development, in particular, the development of structured interfaces and levels of sharing functions. Furthermore, the evaluation of this comprehensive science learning environment is a complex, multifaceted and continuing process, so multiple further researches of the later version need to be done in the pilot school, such as usability test, empirical studies on educational research, and the co-design of curriculum materials. In conclusion, it will be a long journey to pursue research work on the iMOT implementation. The presentation of the segment of iMOT development in this paper is a summary of our partial work, which exhibits our stance to cope with challenges for bridging research and practice on the use of a web-based inquiry learning environment.

References

Ainsworth, G. (1999). The functions of multiple representations. *Computers and Education*, 22(2-3), 101-112.

Chell, T., Urhahne, G., Chan'eb, G., & Ploetner, G. (2010). Collaborative Inquiry Learning: Models, tools, and challenges. *International Journal of Science Education*, 32(1), 109 - 122.

Buckley, B. C., Gobert, J. D., & Paul Horwitz. (2006). Using Log Files To Track Students' Model-based Inquiry. Proceeding ICL 2006 Proceedings of the 4th international conference on Learning sciences.

Edelson, B. C. (2002). Design research: What we learn when we engage in design. *The Journal of the Learning Sciences*, 11(1), 101-121.

Crosslight, L., Unger, C., Day, G., & Smith, C., L. (1991). Understanding Models and Their Use in Science - Conceptions of Middle and High School Students and Experts. *Journal of Research in Science Teaching*, 28(9), 99-122.

Harrison, A. G., & Treagust, G. F. (2000). A typology of school science models. *International Journal of Science Education*, 22(9), 1011-1021.

Linn, M. C. (2000). Designing the Knowledge Integration Environment. *International Journal of Science Education*, 22(1), 11-19.

Leiba, G., & Auldridge, T., & Shea, L. (1999). Teaching & Learning the Basic Science Skills. From www.pen.k12.va.us/OO/Instruction/TL/TLGuide.doc

Chwarz C. G., & Wekwerer, G. (2001). Using a Guided Inquiry and Modelling Instructional Framework (GIMA) to Support Preservice Science Teaching. Published online 1 August 2001 in Wiley InterScience (www.interscience.wiley.com), Inc. doi: 10.1002-1001

Chwarz C. G., & Hite, G. G. (2001). Metamodeling Knowledge: Developing Students' Understanding of Scientific Modelling. *Cognition and Instruction*, 23(2), 111-201

Urhahne, G., Chan'eb, G., Chell, T., Mansfield, A., & Colmese, G. (2010). Role of the Teacher in Computer-supported Collaborative Inquiry Learning. *International Journal of Science Education*, 32(2), 221-231

Hite, G., Frederiksen, J., Slinger, G., Loper, G., & Collins, A. (2002). Inquiry Island: Affordances of a Multi-Agent Environment for Scientific Inquiry and Reflective Learning. In P. Chell, G. Stevens & T. Atwicke (Eds.), Proceedings of the Fifth International Conference of the Learning Sciences (ICLS). Mahwah, NJ: Erlbaum.

Hite, G., & Munstone, G. (Eds.). (1992). *Probing Understanding* (2nd ed.): London and New York: The Falmer Press.

Conclusions and Acknowledgements

This research is supported by the project: Fostering Collaborative Inquiry Modelling and Visualisation Practices in Secondary Science Learning (iMOT) funded by National Research Foundation in Singapore (Project #: F2009-10M001-MO-019, IIM OT Future School-Science project). We would like to thank iMOT team members and our collaborators: Bao Chan, Narel Mous, Fu Eikai, Oon Pey Tee, Teo Quai Eei, Tan Ee Hee, Chan Bin Chuah and their students for working with us on the project.