

# Usability, Learning, and Subjective Experience: User Evaluation of K-MODDL in an Undergraduate Class

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## ABSTRACT

This paper describes an evaluation effort of the use of the Kinematic Model for Design Digital Library (K-MODDL) in an undergraduate mathematics class. Based on CIAO! framework, the research revealed usability problems and users' subjective experience when using K-MODDL, confirmed the usefulness of various physical and digital models in facilitating learning, and revealed interesting relationships among usability, learning, and subjective experience.

## 1. INTRODUCTION

As a National Science Foundation (NSF) supported project, K-MODDL aims to facilitate the teaching of the principles of kinematics and its related theories through digitization of a collection of 19th century kinematic artifacts. K-MODDL thus provides a web-based system that will include navigable moving images of the original artifacts, as well as simulations of the mathematical principles related to the machines' movements. Currently a test web site with more than 10 digitized models is available online (<http://kmoddl.library.cornell.edu/>).

As a part of the NSDL, the goal of K-MODDL is to transform learning for a variety of users, including students at the middle school, high school, undergraduate, graduate levels, as well as lifelong learners. Borgman et al. argued that in order to determine the success of digital libraries one needs to examine whether or not the digital libraries can help the students to achieve pedagogical goals [1]. Various theories have stressed the importance of context and user tasks in evaluating digital library design efforts [2]. Jones et al. proposed the CIAO! framework which evaluates educational software through context, interaction, attitude, and outcomes [3]. However, this framework has not been adopted in the evaluation of digital libraries.

The evaluation part of the project aims to identify and assess ways of integrating K-MODDL into both middle school and university undergraduate classes, in order to facilitate learning and knowledge transformation. The evaluation team includes four Cornell University faculty members, who are using K-MODDL resources in two advanced undergraduate classes and one class in a local middle school. This evaluation research follows the CIAO! framework in the evaluation of K-MODDL. During its ongoing development, the team intends to obtain continuous feedback from different groups of users and to integrate the users'

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Conference '04, Month 1-2, 2004, City, State, Country.  
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requirements into the development and refinement of the digital library. This paper describes the first phase of study, the evaluation of the use of K-MODDL in an undergraduate mathematics class. The focus is on the use of various objects in K-MODDL as pedagogical tools in the specific context of the undergraduate mathematics class.

## 2. RESEARCH PROCEDURE

Following the CIAO! framework, surveys, observations, videotaping, software logging, and web logging were used to capture the context, interaction, attitude, and outcomes of the use of K-MODDL [3]: (1) Context: at the beginning of this research, classroom observations were used to explore the structure and style of the class in order to put the use of K-MODDL in context; (2) Interaction: videotaping was adopted in order to capture the instructor's demonstration of the physical models in the classroom. In the web use session, thirteen students accessed the K-MODDL web site for about 90 minutes, with two students sharing one computer, and discussions between the pair were encouraged. Screen capturing, software logging, and verbal protocol were used to capture the details of the interaction in order to uncover usability problems and learning.; (3) Attitude and Outcomes: in the web use session, the students were asked in the first survey to comment on the difficulties they ran into while using the web site, what they liked about the objects, and suggestions for improvements. The second survey was distributed toward the end of the class and asked specific questions regarding their experience of using different digital objects and how these tools helped them to learn. Web log analysis was used to assess after-class usage of the K-MODDL web site. A final interview with the instructor was conducted after the semester in order to obtain the instructor's view on the usefulness and usability problems of K-MODDL.

## 3. ASSESSING USABILITY, LEARNING, AND SUBJECTIVE EXPERIENCE

*Context:* The course is an advanced course on Euclidean and spherical geometry that emphasizes learning through reason, intuitive understanding and insightful personal experiences relevant to geometry. In order to use various tools in K-MODDL, the instructor set up a class web site that provides sample digital objects. The web site including not only QuickTime Virtual Reality (QTVR) animations and Java simulations of various mechanisms, but also Java simulations of inversions based on Cinderella (<http://www.cinderella.de/>) as well as textual materials.

*Usability:* The first survey revealed many usability problems. The students were asked in an open-ended question about their difficulties when using the digital models. The responses showed that: (1) The major difficulty the students had was the running speed of the Java simulations of mechanisms; (2) Manipulation

also created many problems, for example, students could not move smoothly on the simulation; (3) Typos and grammatical errors were also reported. Classroom observation in the web use session also revealed additional problems. For example, the frames on the main web page caused considerable confusion. In the classroom observations, it was noted that because of many existing usability problems, the students sometimes became distracted from understanding the materials and instead focused their attention on how to make the simulations work. Critical incident analysis of the screen capture movies indicated further usability problems. A critical incident is an event observed within task performance that is a significant indicator of some factor defining the objective of the study [4]. In total, 81 usability critical incidents were identified. On average 11.4 usability problems occurred during one use session. Three types of usability problems were identified: (1) Mental model discrepancies (37 critical incidents). Mental model discrepancy occurred when what the user expected was different from what actually happened, or the users' understanding of a simulation or the web site was different from its actual function; (2) Speed (23 critical incidents). The Java simulations responded slowly or in an awkward way; (3) Bugs in the software (21 critical incidents). This type of problem occurred when the simulation or the browser froze up or crashed.

*Learning:* Outcomes of learning are always difficult to assess in the use of technologies in education settings [3]. In this class, the methods of users' subjective evaluation and critical incident analysis on the process of learning were adopted [4]. The second survey results showed that the Java simulations were rated highest on all three measurements, followed by the textual materials. The physical models were rated third while QTVR animations were rated the least useful. The survey demonstrated that the digital objects are most useful when they are adapted to the purpose and context of the class. When asked about the use of various physical and digital models pertinent to the goals of the class in an open-ended question, most students agreed that the digital models are helpful in understanding geometric principles while physical models are "more fun than educational". Learning critical incidents were discovered through analysis of captured screen movies. Those "ah-ha" moments indicated the new connection being made between different pieces of knowledge. There were 10 learning incidents identified from the 7 movies. The most common incidents are the discovery of rules through manipulation. For example, two pairs of students discovered the conditions under which the circles inverted to straight lines.

*Subjective Experience:* The hedonic value is an integral part of the use of technology [5]. Classroom observation and video analysis of classroom presentations demonstrated that the students were interested and stimulated while they were introduced to the physical models and their history. They showed their interest by smiling and standing up from their seats. Combined with the survey results, this suggests that the physical models are stimulating and engaging. Similarly, according to classroom observation, the digital objects also stimulated the students' interests and curiosity. The students engaged in hands-on manipulation of the objects even before the class started. The animated discussion between the students who were sharing the same computer also indicated their high levels of interest and enthusiasm. The students gave positive responses (10 in 12) when asked about their experience in the survey.

## 4. CONCLUSION AND IMPLICATIONS

This evaluation effort uncovered the usability problems of different digital models and revealed how learning occurred in the students' uses of these models. Usability feedback was provided to the design team and improvements have already been made. Students' positive experience of using the physical and digital models was also revealed. The learning incidents that occurred when the students were interacting with the web site demonstrated that K-MODDL is useful in facilitating the students' understanding and grasp of geometrical rules. However, many usability problems impeded the learning of the students. One interesting finding is that the digital models are actually more useful than the physical ones in facilitating the students' learning. The most useful models were specifically designed for this class. This indicates that K-MODDL is most useful for learning when the materials are re-designed and adapted to the context, objectives and goals of the class.

The relationships among usability, learning, and subjective experience are another interesting finding of this research. For example, good usability is a necessary condition for learning, since the students were frequently busy trying to figure out how make the simulations work, instead of reflecting on the mechanism of the simulation and linking the simulation to the geometrical rules. Effective learning in turn results in a positive subjective experience. For example, the students were elated when they figured out the conditions when a circle inverted to itself. On the other hand, good usability is not necessary for a positive experience. In two cases, the students were amused by the unusual shapes of the simulation, which were actually bugs in the program. In addition, a positive subjective experience can also be detrimental to learning: one student was enjoying playing with the Java simulation of inversion without reflecting on the rules of inversion. The relationships among these three factors -- usability, learning, and subjective experience -- pose interesting questions for the design of digital libraries.

## 5. ACKNOWLEDGMENTS

This research is supported by NSF NSDL Program under Grant No. 0226238.

## 6. REFERENCES

- [1] Borgman, C.L., Gilliland-Swetland, A.J., Leazer, G.H., Mayer, R., Gwynn, D., Gazan, R. and Mautone, P. Evaluating digital libraries for teaching and learning in undergraduate education: A case study of the Alexandria Digital Earth Prototype (ADEPT). *Library Trends*, 42, 2 (2000), 228-50.
- [2] Gay, G., and Hembrooke, H. *Activity-Centered Design: An ecological approach to designing smart tools and usable systems*. Cambridge, MA, MIT Press, 2004.
- [3] Jones, A., Scanlon, E., Tosonoglu, S., Ross, S., Butcher, P., Murphy, P., and Greenberg, J. Contexts for evaluating educational software. *Interacting with Computers*, 11 (1999), 499-516.
- [4] Flanagan, J.C. The critical incident technique. *Psychological Bulletin*, 51, 28 (1954), 28-35.
- [5] Hassenzahl, M., Beu, A., and Burmester, M. Engineering joy. *IEEE Software*, 18, 1 (2001), 70-76.