Creating a Reflective Learning Community: The Role of Information Technology in Genetics Learning

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Informed from the social constructivist perspective and the situated learning theory, which states that learning is a process of enculturation into a community of experts and the retention and application of knowledge depend upon the context in which it is acquired this study investigated an inquiry-based approach to teaching and learning about Mendelian genetics by using tools of information techology. Technology-rich, inquiry-based instructional module for prospective secondary science teachers was designed. Computer simulation was used to scaffold investigation and model construction. Intertwining design and research is particularly important for establishing collaborative context and cultural structure that support collaboration. Key findings included pre-service teachers' initial limited abilities to create evidence-based arguments; their hesitancy to include inquiry in their future teaching; and the impact of collaboration on thinking.

Keywords computer simulation; science learning; community of practice

1. Introduction

Without a doubt, computer technologies are useful and valuable in improving the level of science teaching. Yet, the question "What are the most effective ways for science teachers to enhance students' learning of science using computer technologies?" still needs an answer. Informed from the social constructivist perspective and the situated learning theory, which states that learning is a process of enculturation into a community of experts and the retention and application of knowledge depend upon the context in which it is acquired this study investigated an inquiry-based approach to teaching and learning about Mendelian genetics by using tools of information techology. The context for the study was a teaching and learning course focused on inquiry and technology for prospective secondary science teachers. According to social constructivist perspective science learning can be viewed as a participatory process that includes the negotiation of the cultural practices of scientific communities. Intertwining design and research is particularly important for establishing collaborative context and cultural structure that support collaboration. It is assumed that students need to engage collaboratively in inquiry by asking and refining questions, designing and conducting investigations, gathering and analyzing data, making interpretations, drawing conclusions, and reporting findings in a social context. It is argued that structuring scientific inquiry as investigation, leading to development of explanations, provides a meaningful context for learning about inquiry and science content. In addition, prospective teachers know very little about effective use of information technologies in education. It is imperative that they receive a sound amount of instruction about technology and its use in educational settings. They need to engage in such technologies as learners in order to master and use the same technology in the future in their own science classrooms. Technology-rich, inquiry-based instructional module for prospective secondary science teachers was designed.

The National Science Education Standards (NSES) articulate a vision of a teacher who acts as a critical decision maker, intervenes in the learning process at appropriate times in an effort to encourage, challenge, and focuses students [1]. Although, research produces a "pattern for general support for inquiry-based teaching" [2–4]. Von Secker and Lissitz [5] noted that little research was available describing the

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occurrence of NSES research based teaching strategies being utilized in science classrooms, Teacher-centered instruction and text-based learning were still "typical" throughout the 1990s.
Teaching science as inquiry is a very complex activity by nature: teachers have difficulties implementing inquiry into their teaching repertoire for various reasons [6]. Teachers who want to use inquiry learning are faced with a number of questions about identifying instructional materials that support inquiry. One of the challenges of helping prospective science teachers to learn about scientific inquiry is embedding their work in appropriate social context and creating a culture of collaboration and inquiry.

2. Theoretical Framework and Implementing Technology into Science Classroom

Design-based research [7] is an emerging paradigm for the study of learning in context through the design and study of instructional strategies and tools. This module was designed to engage prospective science teachers as learners in an exemplary inquiry based module for developing knowledge and skills addressed in teaching standards. Consistent with current science education standards and theories of cognition, our module was shaped by the social constructivist and socio-cultural views of learning [8–10]. According to this line of thinking, science learning can be viewed as a participatory process that includes the negotiation of the cultural practices of scientific communities. These cultural practices include constructing explanations, defending and challenging claims, interpreting evidence, using and developing models, transforming observations into findings, and arguing theories. In this framework, learning is regarded as a participatory process in which the learner gradually becomes an active member in a cultural community by learning its discourse practices, norms, and ways of thinking. From this perspective, knowing refers to belonging, participating and communicating.
One kind of learning technologies are computer simulations, they can be used to improve the teaching of scientific processes along with the content. Simulations provide a unique opportunity for students to interact with the dynamics of a model system and help them to conceptualize it [11]. Computer simulations enable repeated trials of an experiment with considerable ease in a limited time, provide immediate feedback, allow simultaneous observation, and offer a flexible environment that enables students to proceed with their own plans [12–13]. Computer simulations encourage the use of "what if" questions and support students to think hypothetically and test their hypothesis by identifying and controlling variables [14]. Stratford [15] and Windschitl & Andre [16] have reported that learning technologies designed within coherent instructional contexts can lead to improved science concept learning. However, there is still a need for connection of such conceptual learning with development of a broad range of scientific inquiry skills. Mendelian Genetics Computer Simulation, CATLAB, is a software program that allows students to generate various characteristics in cats and explore the inheritance of those characteristics [17]. CATLAB is based upon a valid scientific model of a genetic population. The simulation is used as a medium that has the potential to involve learners actively in science inquiry and in the learning of science. CATLAB enables students to select traits, hypothesize about gene interactions, and test these hypotheses by crossing selected cats. The traits students can investigate with CATLAB include coat color (white/nonwhite), white spotting extensive/some/none), density of pigment in the fur (agouti/non-agouti), tabby striping (mackerel/blotched), and the presence of a tail (tail/Manx) (see Figure 1.)

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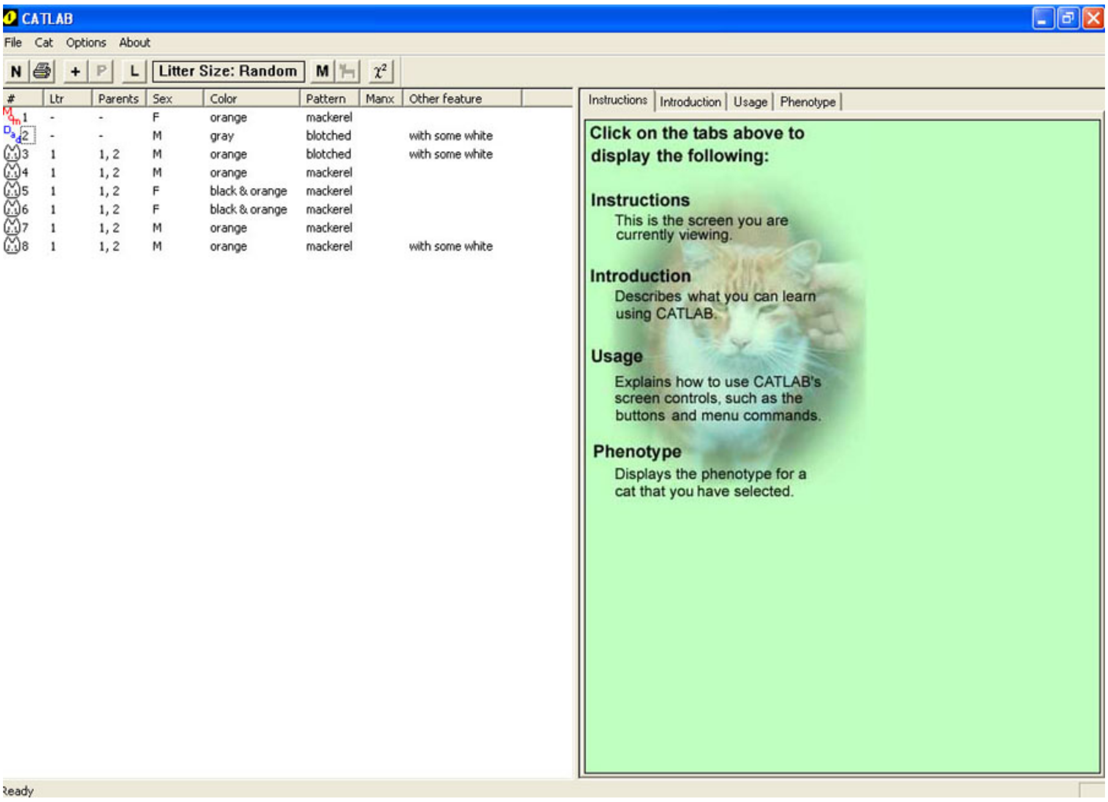

Fig. 1 Screenshot of Catlab simulation**.**

3. Methodology and Data Analysis

We designed the instructional module and used qualitative research methodology to answer the research questions. The instructional module engaged prospective teachers in an inquiry activity in which they were asked to explore inheritance patterns in cats that required testing hypotheses and making predictions. Computer simulation was used to scaffold investigation and model construction. Broad range of data was collected to support naturalistic inquiry.

3.1 Research questions

Due to the complexity of studying the classroom interactions of this preservice teacher classroom, we crafted the following research questions: (1) How can a learning community be constructed with prospective science teachers and what were their perceptions of using technology tools as a learner? (2) What were the prospective teachers' understandings of inquiry with computer simulation and Mendelian genetics following the module?

Participants' reflective journals provided rich data. Interview analysis revealed that participants cited following experiences as important: 1) developing critical thinking, 2) developing inquiry skills, 3) initial frustration in the process, 4) lack of immediate answers, 5) losing self-confidence, 6) questioning their experimental design 7) valuing the peer discussions and learning from peers. Inquiry skills on communication, interpreting data and designing an experiment were mastered by students. Owing to computer simulation the students were able to run many simulations in a short time and compare the results of a set

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of experiments. This contributed to their understanding of controlling variables. Key findings included pre-service teachers' initial limited abilities to create evidence-based arguments; their hesitancy to include inquiry in their future teaching; and the impact of collaboration on thinking. We cannot teach process of science without content.

3.2 Data sources

Data collected through the questionnaires and follow-up interviews provided confirmatory evidence for teachers' initial views of learning community and inquiry using simulation, and also of their developing understandings. To evaluate prospective teachers' understandings of Mendelian genetics concepts, we administered pre/post instructional tests, adapted from Simmons & Lunetta [18].

Table 1 Relationship of components of inquiry to CATLAB.

Generating ideas	Questions for or as a results of inquiry
	Hypothesis or rules of relationships between variables
	Explanations (causal relationships)
Gathering data	Data from crosses in Catlab
	Generating and selecting relevant data
Evaluating results	Data analysis; Logical and conceptual consistency
	Considering experimental evidence and constructing arguments using this evidence
	Considering alternative explanations
Content	Domain specific content knowledge
	Domain specific cognitive skills, such as punnet squares

4. Conclusions and Implications

Socially constructed processes like negotiation, consensus, and collaboration with peers and instructor played very important role in directing cognition and triggering individual reflection. Guidance from peers who had more expertise and instructor was also invaluable in developing understandings about inquiry processes and Mendelian genetics concepts. Debate facilitated learning conceptual knowledge while peer interaction and guidance nurtured procedural knowledge. Instead of attributing poor performance to cognitive deficiencies, taking Lave & Wenger's [19] and Brown & Campione's [8] advice and looking at the extent to which our participants became part of communities of practice that value the use of data, evidence, testing, and peer's findings. Communities in which prospective teachers negotiate, construct argumentations, and practice persuasion. In the beginning prospective biology teachers considered themselves as experts not only they did not pay attention to their peers findings but also they failed to test, using Catlab, some of their early predictions, instead jumping to a conclusion and making claims with no supporting evidence. Therefore when they were presented with so many discrepant events, they were confused, frustrated, and lost their self confidence. The implication is that to support prospective teachers' conceptual and procedural knowledge about science content as well as scientific inquiry within an inquiry based module, it is advised to have (a) debate about their conceptual knowledge (b) subject their consensual positions to testing (c) and reach a consensus and draw conclusions.

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Fundamental processes of scientific inquiry can be demonstrated, exercised, and incorporated into instruction by employing technology tools, such as Catlab. Being able to generate data and build relationships between variables, make predictions, form hypotheses and test them, and to construct and modify scientific models that can explain and account for data, all helped us to engage our prospective teachers in science as inquiry. Our technological tool not only provided a context for carrying out an inquiry activity and learning about Mendelian genetics content, but also presented an example for prospective science teachers on how to use such a tool in their future classrooms. Using Catlab teachers can ascertain students' analytical pathways in testing hypotheses. Teachers can, therefore, identify the loci of students' impasse in inquiry processes and underlying genetics concepts. We need studies which investigate how instructions using simulations can be designed in order to effectively enhance students' scientific inquiry processes and support students' concept learning in science.

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