ISSN 1648-3898

ENHANCING MENDELIAN GENETICS CONCEPTS USING A GUIDED COMPUTER-MEDIATED INQUIRY

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Abstract. *The purpose of this study was to situate prospective secondary science teachers in an authentic scientific investigation, that of hypothesis testing of inheritance patterns of cats, and then to examine prospective teachers' developing understandings of basic Mendelian genetics, scientific inquiry, and their perceptions of the learning environment. The context of the study was a teaching and learning course focused on inquiry and technology. Data obtained from the twelve participants included: a) pre-post tests of Mendelian genetics concepts; b) videotaped class presentations; c) inquiry project reports; d) audio taped semi-structured interviews; and e) classroom discussions and observations. The findings suggest that engagement in hypothesis testing, within a socio-constructivist framework; can be used to support the integrated acquisition of conceptual knowledge in science. After the module, there was clear evidence that inquiry-based instruction, enriched with computer simulation and collaboration, promoted students' conceptual understanding of Mendelian genetics and understandings of scientific inquiry.*

Key words: *hypothesis testing, inquiry-based teaching, learning genetics, modeling in science.*

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Introduction

Inquiry-based teaching practices 'demands a set of teaching practices quite different from typical didactic science instruction' (Sandoval & Daniszewski, 2004). Researchers have indicated that translating inquiry-based teaching into classroom practice is a very challenging task for science teachers (Keys & Kennedy, 1999; Tobin, Kahle, & Fraser, 1990). In order to yield desired outcomes in students' abilities and understandings, inquiry-based teaching should require the "conceptual identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (NRC, 1996, p. 23). In inquiry-based teaching, students participate in investigations that require them to develop questions and hypotheses, collect data, analyze data, and draw and test conclusions (NRC 1996; 2000). A number of studies suggest that inquiry-based science teaching cultivates scientific literacy, knowledge of science procedures, conceptual understanding, and critical thinking (Apedoe & Reeves, 2006; Kirschner, 2006; Sandoval, 2005); allows students to experience processes as questioning, evidence gathering and analysis (Edelson, 2001); and fosters the development of deep foundational knowledge in a content area (Bransford, Brown, & Cocking, 2000).

The primary goal of this study was to situate prospective secondary science teachers in an authentic scientific investigation, that of hypothesis testing of inheritance patterns of cats, and then to examine prospective teachers' developing understandings of basic Mendelian genetics and scientific inquiry. An inquiry-based learning environment was created for prospective secondary teachers, in order to strengthen their conceptual understandings in the critical area of genetics using an inquiry-based approach. The structure of the instructional module is described and prospective teachers' developing understandings of the inquiry-based instruction is tracked. A centrepiece of the instructional module was a computer-based investigation based on a model of inheritance in domestic cats.

Problem of Research

The following research questions guided the study:

1. To what extent, if at all, did prospective teachers develop understandings about basic Mendelian genetics?
2. What were the prospective teachers' perceptions about the learning environment?

The rationale for this study relates to the importance of science teachers in engaging students in science inquiry and learning about what science is; in particular, in supporting students' scientific reasoning and the use of evidence in developing explanations of phenomena.

Research Focus

The theoretical framework for this study is based on a social constructivist perspective. 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. One of the challenges in helping prospective science teachers to learn about Mendelian genetics is embedding their work in appropriate social context and creating a culture of collaboration and inquiry (Vygotsky, 1978; Wenger, 1998). The construct of *community of learners* contributed to our curricular framework, and is consistent with current national science education standards (NRC, 1996). Theories of cognition argue that developing understanding occurs in actual context of use (Brown & Campione, 1996; Lave & Wenger, 1991). The negotiation of understanding arises from the context of the investigation in the classroom, and it is achieved through constructive discussion, questioning, and criticism. Discourse involves increasingly scientific modes of thinking, such as conjecture, speculation, evidence, and proofs which become part of the common voice of the community of learners (Brown & Campione, 1996).

A component of scientific inquiry is hypothesis testing, that has recently been presented very positively within the science education community (Howe, Tolmie, Duchak-Tanner, & Rattray, 2000). The drive has come from reform documents, which emphasize the integrated acquisition of conceptual and procedural knowledge. In principle, hypothesis testing should allow integrated acquisition of knowledge.

Studies related to learning technologies point to the effectiveness of integration in instructional contexts, which can lead to enhanced science conceptual understanding (Sandoval & Reiser, 2004; Stratford, 1997). Computer simulations enable repeated trials of an experiment with considerable ease and in a limited time, provide immediate feedback, allow simultaneous observation, and offer a flexible environment that enables students to proceed with their own plans (Fisher, 1997).

One area of biology in which learners have difficulties is genetics; essentially, the conceptual area of genetics investigates biological patterns of inheritance and variation (Johnson & Stewart, 2002). A survey of high school teachers indicated that Mendelian genetics, meiosis and mitosis, and the chromosome theory of inheritance were considered among the most difficult, as well as the most important, topics of study for high school students (Stewart, 1982).

Hafner & Stewart (1995) implemented a model-revising approach in problem solving in genetics framework to analyze students' heuristics. They reported that students used three general heuristics during model construction: search the model, test the model, and evaluate the model. Students revised their models and evaluated them with respect to both the model's explanatory and predictive sufficiency using the simulation, and the majority of students in this learning environment produced successful solutions to genetics problems. Similarly, Finkel (1996), found that students using the Genetics Construction Kit GCK) computer program were able to engage in model-revising problem solving successfully and were able to produce revisions of increasing complexity that were generally compatible with accepted scientific theory.

Methodology of Research

General Background of Research

The context for the study was a newly developed teaching and learning course focused on inquiry and technology. The course was the first in a series of three teaching and learning courses. It was required of all secondary prospective teachers in a teacher education program in a large university in eastern United States. The instructors engaged prospective teachers in discussions of scientific inquiry, the nature of science, and instructional technology.

The twelve participants in this study were all the students who had enrolled in this course. Biographical and background information was collected from participants (see Table 1). Participants were asked if they had taken any history and/or philosophy of science courses, and to describe their past research experiences, if any.

Table 1. Participants' Biographical Data and Research Experiences.

Name	Class	Major	Past research experience	His. Sci. Course	Phil. Sci. Course	Biology Courses (total number)
Lisa*	MS	Biology	Significant	No	No	9+
Wilson	Senior	Biology	None	No	No	9+
Karen	MS	Biology	None	No	No	9+
Rachel	Senior	Biology	Some	No	Yes	9+
Mary	MS	Physics & Mathematics	Significant	Yes	Yes	None
Ben	Sophomore	Earth & Space Science	None	No	No	One introductory
Kevin	Junior	Earth & Space Science	Some	Yes	Yes	One introductory
Ashley	Junior	Earth & Space Science	None	Yes	No	One introductory
John	Junior	Earth & Space Science	Some	No	No	One introductory
Mike	Junior	Earth & Space Science	None	No	No	One introductory
Valerie	Senior	Earth & Space Science	None	No	Yes	One introductory
Kate	Junior	Chemistry	None	No	No	One introductory

** Boldface indicates focus participants who were interviewed*

This study was a qualitative case study which employed grounded theory traditions' data analysis technique; namely, constant comparative method. Data from twelve participants provided rich contextual data and was deemed sufficient to answer the research questions. Quantitative findings such as pre and post-test results were not meant to be generalized but to shed light on participants' enhanced understandings and provide support for more in-depth qualitative analysis. Primary data source was interviews with purposefully selected (Patton, 1990) participants.

Mendelian Genetics Computer Simulation (Catlab)

Catlab (Kinnear, 1998) is a computer simulation that allows students to generate various characteristics in cats and explore those characteristics by crossing specific cats (Kinnear, 1998). Catlab is designed for use in high school and undergraduate biology classrooms and, with appropriate scaffolds; it can also be utilized in middle school curricula. Students can collect and interpret data and draw inferences and conclusions about the nature of specific inheritance patterns by using the program to "mate" specified cats. Catlab was used to involve prospective secondary science teachers actively in science inquiry and in the learning of Mendelian inheritance. The selection of the simulation, Catlab, was based upon several criteria, including the open-ended nature of the program. Catlab is based upon a valid scientific model of an accurately depicted genetic population. Furthermore, most students have had common experiences with cats.

Students using Catlab are required to examine, organize, and analyze data for patterns. Solution of the Catlab project problems involves hypothesis-testing and experimental design in addition to the use of mathematical procedures. The participants must, through skilled experimentation, gather data that is meaningful enough to deduce the mode of inheritance.

During a series of class sessions the author, as lead instructor of the module, engaged the prospective teachers in investigation, as they explored inheritance patterns in cats that required testing hypotheses and making predictions. Instruction was aimed for an environment of collaborative inquiry, which involves cognitive interactions between both teacher and students, and students with each other (Crawford et al., 2005). See Table 2 for the sequence of the activities in these sessions.

Table 2. Class Sessions and Description of the Module.

Session	Description of Activities During the Module
1	• Introduction to Mendelian genetics: Major concepts and operations were presented by the volunteer students who majored in biology; followed by class discussions of exercise problems which were provided by the instructor • Introduction to *Catlab*: The instructor demonstrated how to use the computer simulation
2	• Sample *Catlab* investigations were carried out by the instructor to demonstrate how to collect data and work with the program during hypothesis testing • Student pairs used *Catlab*, testing another hypothesis on their own • Class discussion of the activity and evaluation of the proposed solutions
3	• Student pairs worked on their guided inquiry projects • Discussion of probability, Mono and Dihybrid crosses
4	• Preliminary project presentations to peers • Continued work on inquiry projects
5	• Continued work on inquiry projects • Instructor-led class discussion of observation vs. inference and assumption vs. evidence to scaffold participants' understandings
6	• Continued work on inquiry projects • Discussion of building and testing hypotheses and the role of models in science
7	• Final inquiry project presentations

Not all participants had the discipline background related to the Catlab investigation. In order to provide some subject matter background information the following major topics were reviewed: Mendel's laws of heredity; Monohybrid - Dihybrid crosses, including concepts such as dominant, recessive, allele, homozygous, heterozygous; Multiple -alleles and incomplete dominance; Sex-linked inheritance. Following this review, the author demonstrated how to use the Catlab software to test hypotheses. The twelve participants were paired according to their majors and spent time working on example problems. Finally, participants were given four driving questions, and asked to choose one question for their inquiry project, with an option to come up with their own question.

The six pairs of participants worked on their inquiry projects at separate work stations; all pairs selected their driving questions from the list they were given two questions were investigated by two

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groups. At the end of the module, each pair presented their model to their peers, and the pairs explained how their models could account for results of particular crosses.

Data Sources and Methods of Analysis

Mixed methods research design (Johnson & Onwuegbuzie, 2004) and multiple data sources were used to determine the influence of the investigation on prospective teachers' understandings (See Table 3 for design of the study). The multiple data sources used in this part of the study included: a) pre-post tests of understandings of Mendelian genetics concepts; b) videotaped class presentations; and c) audio taped semi-structured interviews.

Table 3. The design of the study.

Pre-instructional Genetics Survey	*Catlab software*	**Mendelian Genetics Questionnaire**
←	**Module**	→
Students' background information	**Inquiry project reports**	Semi-structured Interview Protocol
Before	**Classroom Observations**	**After**
	During Instruction	

Participants' knowledge of genetics concepts was measured using the pre and post genetics questionnaires. Furthermore, understandings of Mendelian concepts were inferred from inquiry project reports, post interviews, and classroom discussions and observations. Pre and post tests were adopted from Simmons & Lunetta (1993). The tests included propositions from three domains, namely gamete combination, transition of inheritance, and probability. Table 4 shows item numbers and their corresponding propositions. The pre-test included twelve items containing multiple choice and open-ended items. The post-test included a total of eighteen items. Ten pre-test items were embedded in the post-test in a different sequence to compare changes in responses.

Table 4. Genetics Test Items' Corresponding Domains of Propositions.

Item Number:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Proposition	GC	GC P I	GC P	GC P	*	GC P I	GC P	GC I	GC I
Item #	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Proposition	*	GC	GC P	GC P	GC I	GC P I	GC I	GC I	*

*GC: gamete combination; P: Probability; I: Transmission of inheritance. *Item 5 and 18 were definitions of phenotype and the genotype respectively and item 10 was about forming a hypothesis.*

Semi-structured interviews were conducted to further probe some of the prospective teachers' understandings of Mendelian genetics. A total of seven participants were interviewed at the end of the module. Participants from different backgrounds (e.g. physics, earth and space, biology) were purposively selected for interviews (Patton, 1990). All of the four prospective biology teachers, two prospective Earth and Space science teachers, and one prospective physics teacher were selected for post-instructional module interviews. One additional participant was interviewed because she demonstrated remarkable progress during the module. Participants who were interviewed are highlighted in Table 1. Inquiry project reports were collected from each pair and final project presentations were videotaped. Each pair recorded their investigation procedures and data in their reports.

All interview data were analyzed with the help of NVivo, qualitative data analysis software. After transcribing all seven interviews data analysis was started with 20 sociological codes that were constructed after reviewing the related literature. To ensure dependability and consistency, two post-doctoral fellows agreed to code interview transcripts independently. Consensus was reached during numerous phone conversations on coding, categories, emerging themes, patterns, and discrepancies.

Results of Research

In this section, results are organized around themes as they relate to understandings of Mendelian genetics concepts and learning environment

Research Question 1: To what extent, if at all, did prospective teachers develop understandings about basic Mendelian genetics?

Following the module prospective science teachers demonstrated enhanced understandings of Mendelian genetics concepts. Mendelian genetics pre and post-test items measured propositions in three domains, namely gamete combination (GC), transmission of inheritance (I) and probability (P). Some items fell into more than one domain. (See Table 3 for item numbers and their corresponding propositions.)

According to pre-test results most of the participants, including the biology majors, did not hold a strong conceptual understanding of Mendelian genetics. At the beginning of the module most participants demonstrated a very mechanistic understanding of gamete combination and probability. Post-test results showed considerable improvement. The average correct response in pre-test was 39%. Average correct response on the same items on the post-test improved to 67%, Figure 1. The biology majors did not score higher than other participants in the pre-test. In spite of their extensive coursework in biological sciences, they did not have firm conceptual understandings of Mendelian genetics.

Participants appeared to struggle the most with the concept of probability. The items with the lowest correct responses dealt with determining genotypes of individuals and probability and its relationship to sample size. Related to their less than robust understanding of probability was their use of Punnett square without conceptual understanding. Almost all the prospective teachers knew how to construct and use a Punnet square for solving genetics problems; yet, the conceptual knowledge and cognitive operations behind the Punnet square were mostly absent. Another problem was that they frequently used the concepts of allele and gene, interchangeably.

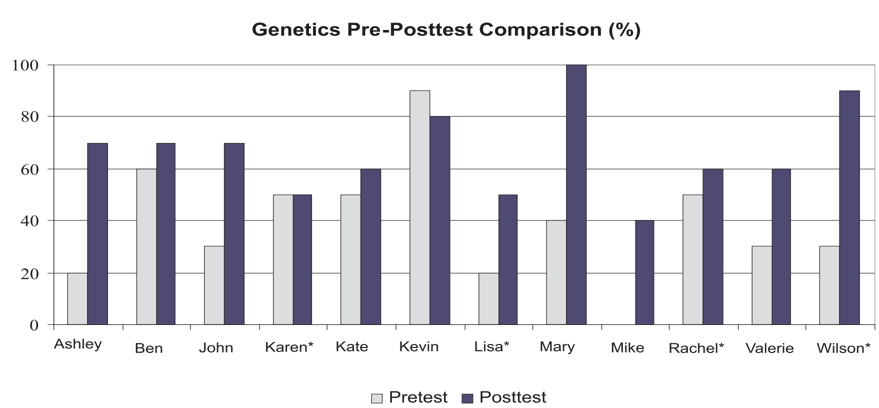

Figure 1: Percentage of correct responses in pre and post genetics tests (*Biology major).

ISSN 1648–3898

Revealing Alternative Conceptions

A number of alternative conceptions about genetics principles were revealed during inquiry projects. The most prevalent of these dealt with the Punnett square. Other misconceptions included:

The phenotype that appeared the most as a result of the crosses between cats with different phenotypes is the dominant trait

A cross between two cats with different phenotypes producing cats with only one phenotype means that the phenotype is the dominant trait, and the parent must be homozygous dominant

If a trait is not common in the population, then it must be recessive.

Dominant and recessive traits can be heterozygous

The number of correct responses on post-test items for each participant is reported in Figure 2. The majority of participants responded correctly on definition items, but had more difficulty with items requiring application and analysis of genetics concepts. This was true even when information was supplied in the text of the problem.

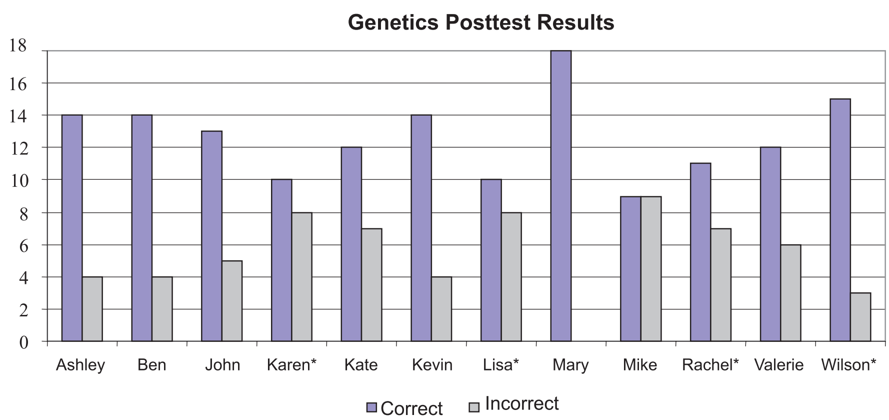

Figure 2: Number of correct and incorrect responses on post-test (*Biology majors).

All pairs came up with well substantiated answers to their driving inquiry questions. In fact, at the end of the final presentations they were able to identify a total of seven genes and their interaction to one another. Basically they identified the inheritance model that the Catlab program was built on. When they were asked if they learned Mendelian genetics as a result of their experiences in this module they self reported:

> I learned about genetics through experimentation and trying different things and seeing what happens in Catlab program. We did crosses and had to come up with explanations (Ben).

Mary received an undergraduate degree in physics and mathematics, and she never had a biology class in college. She expressed a great deal of frustration, in the beginning of the module. In the end, Mary demonstrated the most significant progress by correctly answering all the questions in post-test. She was also very successful during inquiry project investigations. She had had prior research experience; "I spent two summers in Oak Ridge and a year in grad school, just taking data, writing it down" (Mary). In her interview she said:

> I definitely learned about Mendelian inheritance. Explaining why I have blue eyes and my parents don't… yeah, I can explain my cat. It was very exciting. I can write out some of the genotypes on my cat. I know what she is (Mary).

Although she was biology major, Karen reported that she did not take full semester of genetics class. Instead she was introduced to Mendelian concepts in her other bio classes. Similarly Lisa, biology major, stated that her genetics knowledge increased after the module.

In summary, prospective science teachers learned about Mendelian genetics concepts during their investigations. The most problematic issues had to do with concepts of probability. It appeared that Mary's success in this module was related to her understanding of probability. "I knew how to do it once I had the terminology, because it's really just probability theory" (Mary). These kinds of experiences are very rare, not only in science teacher education programs, but also science departments, as it is evident in Rachel's following statement:

> "None of us really used to do anything like that. Until now it has always been very structured research experience that is another reason that this experience was valuable" (Rachel).

The interview evidence suggested that participants were engaged in multiple inquiry processes in response to Catlab project. For example, one pair was observed generating a quantitative relationship that predicted 3:1 ratio in phenotypes of the offspring; evaluating the empirical consistency of the relationship for different parents and modifying their initial relationship to suggest that there is 2:1 ratio in phenotypes. They generated an explanatory model to answer the question from the teacher and the peers, and they modified the original relationship to include a lethal gene concept as a variable based on problem solving strategy.

Participants learning included the processes of generating qualitative and quantitative relationships between traits; evaluating the empirical consistency of the relations between genes by examining phenotypes of the offspring; and modifying these relationships according to interpretation of the data gathered. In addition, participants encountered discrepant information in Catlab and expressed their surprise when they discovered a particular relationship was not valid. Participants were observed designing a new test based on discrepant information to confirm their findings. Additionally, selecting extremes may encourage "what if" scenarios that also helped learners to evaluate the consistency of the relationship. There was ample evidence that working with Catlab enabled participants to evaluate and modify hypotheses.

Research Question 2: What were the prospective teachers' perceptions about the learning environment?

Participants gave largely positive responses related to their perceived value of the peer interactions, project investigations, and classroom presentations. Interview analysis revealed that participants cited the following experiences as important: 1) developing critical thinking, 2) developing inquiry skills, 3) ill-structured nature of the process, 4) initial frustration in the process, 5) losing self-confidence, 6) revising experimental design, 7) valuing learning from peers, and 8) satisfaction of discovery.

Both positive and negative feelings about inquiry were expressed during the interviews; attitudes towards inquiry were mostly associated with past learning experiences, general personality, and lack of inquiry experiences. Ben and Kevin, majored in Earth and Space science, and as a pair, were very successful with the Catlab project, and they enjoyed the experience. They both had a curious and a competitive nature, and according to them "they want to know stuff". After answering their project question they wanted to explain more and were testing different hypotheses, When Ben was asked to describe when they finished their project, he replied:

> I don't think we ever felt like we were done, until we were sitting after final presentations with the list of genes on the board and you said congratulations you found all the genes (Ben).

Despite these positive views, some participants had negative feelings toward inquiry. They stated they preferred a more structured, teacher-centred learning environment. Although Karen believed inquiry-based learning was beneficial, she also identified her frustrations during the module.

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> I like to have answers immediately. Having to figure out how to get to the answer at times drives me nuts. (Karen).

Similarly, after successfully completing her inquiry project and having a sound understanding of Mendelian genetics, Mary preferred receiving direct instruction about inquiry-based learning. She said:

> Honestly. I want someone to sit down with me and lecture me about it; like do non-inquiry things about inquiry, just so I can sit down and go, 'oh, that's what I'm supposed to be doing (Mary).

Overall, prospective science teachers' views about the Catlab software were highly positive, although some had mixed emotions about it. They enjoyed the program, as it related to their lives. Many of them had cats at home. Mary expressed, 'I can explain my cat; it was very exciting'. Kevin majored in Earth and Space science and had little biology background; he enjoyed working with Catlab. In his interview he said:

> No matter who you are and what background knowledge you have you can understand and learn what is going on in this program (Kevin).

Participants were pleased with the classroom atmosphere and often talked about how it was very helpful to collaborate with peers. Experiencing inquiry in such environment also prompted participants to reflect about aspects of nature of science. All interviewees cited the value of peer interaction and collaboration. For example, when Karen was asked about the preliminary presentations, she said:

> It was really good how we met a couple times go over, we didn't agree with everything from the other groups, it actually helped us (Karen).

Important Role of Preliminary Presentations

In the middle of the module we interjected a time for preliminary project presentations. During this time participants had a chance to see what other pairs had done, up to that point. They had an opportunity to compare and contrast their data, findings, and conclusions with their peers and evaluate their developing project. This activity proved to be very valuable. It provoked heated discussions and debates between pairs. Some of the participants became aware of more evidence that supported their claims and models, while others recognized alternative as well as contradictory explanations and models.

Ben and Kevin also valued the preliminary presentations and their role:

> Presentations gave us different ways of looking at data; we'd say maybe that can apply to our model (Ben).

Preliminary presentations helped the participants to develop conceptual and procedural understandings by creating an environment for them to articulate their thinking. Making their understandings and predictions public helped them to monitor their progress and revise their inquiry strategies. Participants became aware of questions, such as "Did we have enough and/or relevant evidence," "Did we finish explaining our hypotheses,"; "Did we have a complete inheritance model." Trying to answer such questions helped participants to evaluate their progress and frame their inquiry around articulating knowledge claims and providing evidence to support such claims.

Discussion

Assertion: Many prospective teachers, even biology majors, possess a weak conceptual understanding of Mendelian genetics and a simple, mechanistic understanding of gamete combination and probability.

Participants initially did not demonstrate deep conceptual understandings of Mendelian genetics concepts and their understandings were enhanced after the module. In the genetics pre-test 10 out of 12 participants correctly responded to less than 50% of the questions. The genetics pre-test revealed that most of the participants did not have strong conceptual understanding of Mendelian genetics, and they had a very mechanistic understanding of gamete combination and probability at the beginning of the module.

Results indicate that the designed science learning environment supported the participants' conceptual elaboration of Mendelian inheritance. The analyses of pre- and post-tests suggest that there were qualitative positive changes in the nature of the participants' explanations. Moreover, the average percentage of correct responses in the pre-test was 39%. Surprisingly, the biology majors' average percentage (38%) was not higher than the average percentage for participants majoring in other disciplines (40%). In spite of their extensive coursework in biological sciences, the biology majors lacked a deep conceptual understanding of Mendelian genetics. The average percentage of correct responses improved from 39% on the pre-test to 67% on the post-test.

The findings suggest that engagement in hypothesis testing, within a socio-constructivist framework; can be used to support the integrated acquisition of conceptual knowledge in science. Debate facilitates conceptual learning, whereas guidance in any form, whether from teacher, peer, or software, facilitates procedural learning. Individual reflection is also crucial to conceptual knowledge acquisition. Prospective teachers not only consistently tested their hypotheses and supported their knowledge claims by evidence, but most of them also evaluated alternative hypotheses during their investigations. 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 the instructor was also invaluable in developing understandings about inquiry processes and Mendelian genetics concepts.

Prospective biology teachers, despite their assumed stronger background in content, were no more successful than other participants. There could be several contributing variables; one possible reason could be the way each problem was presented. Both pairs who majored in biology were working on problem number one, which was probably the most comprehensive question. Although as one other participant articulated "all questions came to: who can explain inheritance pattern in cats" pairs who focused on other questions were relatively more successful in their investigations, therefore the difficulty level of the inquiry task should be in accordance with learners' ability and understanding level.

Another explanation for this situation is, instead of attributing poor performance to cognitive deficiencies, we could attribute it to Lave & Wenger's (1991) and Brown & Campione's (1996) ideas of how participants became part of communities of practice. 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 scientifically, some of their early predictions. Instead, they jumped to a conclusion and made claims with no supporting evidence. Therefore when they were presented with so many discrepant events, they were confused, frustrated, and lost their self confidence. A community of practice values the use of data, evidence, testing, and peer's findings. Further communities provide for negotiation, constructing arguments, and practicing persuasion. The implication is that to support prospective teachers' conceptual and procedural knowledge about science content within an inquiry based module, it is advised to have opportunity to (a) debate about their conceptual knowledge (b) subject their consensual positions to testing, and (c) reach a consensus and draw conclusions.

As in previous research (Sandoval & Reiser, 2004; Windschitl, 2003), our study suggests that prospective science teachers need to engage more substantially in inquiry-based learning experiences, than in many traditional teacher education programs and engage in these early in their preparation.

Carefully designed instruction is of utmost importance in an undergraduate course that adopts

ISSN 1648–3898

an inquiry-based pedagogy, enriched with technology. One must take into account course objectives, course content, task characteristics, instructors' roles, students' roles, technological affordances and assessment strategies, (Apedoe & Reeves, 2006).

Conclusions and Implications

Situating prospective science teachers as learners of science in this module served as a powerful way to think about the role of inquiry in teaching and learning. After the module, there was clear evidence that inquiry-based instruction, enriched with computer simulation and collaboration, promoted students' conceptual understanding of Mendelian genetics. Participants generated qualitative and quantitative relationships between traits; evaluated the empirical consistency of the relations between genes; and modified these relationships according to interpretation of the data. Participants developed an understanding of basic Mendelian genetics and demonstrated some expertise in genetics problem solving in hypothesis testing situation. Change is difficult and it requires time. Considering the relatively short period time, 4 weeks, in this module, participants demonstrated a noteworthy progress.

Findings of this study appear positive, yet we do not know the lasting impact from such a limited experience. Longitudinal research studies are needed to fully understand the effect and durability of such experiences over time, and the extent to which prospective teachers can translate their newly formed understandings into their own practice.

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Received: *March 17, 2011* Accepted: *August 17, 2011*

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