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ABSTRACT

In this study, the nature of scientific explanations generated by two groups of prospective elementary school teachers were studied in the context of a life science course. Both groups participated in long-term investigations of insect cultures in which they crafted testable questions based on observations, designed experiments, collected and interpreted data, constructed explanations and explored alternatives, and communicated their explanations to peers. One group used the Progress Portfolio, a tool designed to promote reflective inquiry. It is a software shell that allows teachers to craft templates that are used by students to guide them through complex tasks. Twenty-five prospective teachers, in four small groups (two to four teacher candidates) each semester participated, approximately half in a Progress Portfolio semester, and the rest in a semester not using Progress Portfolio. Findings show substantial differences in the scientific explanations developed by prospective teachers who used Progress Portfolio and those who did not. In the non-Progress Portfolio semester, none of the four groups were able to generate an evidence-based explanation for their experimental findings. The four groups in the Progress Portfolio semester developed an explanation for the results of their long-term science investigations. The scaffolds in the Progress Portfolio were useful for making connections between an existing knowledge base and what was being learned from the investigation. Nine appendixes contain some sample pages from the prospective teachers developed pages. (Contains 41 references.) (SLD)

Supporting Prospective Elementary Teachers in Developing Scientific Explanations using *Progress Portfolio*

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Background & Purpose

Contemporary reform efforts in science education call for science teaching that supports all students' meaningful learning (e.g., Mintzes, Wandersee & Novak, 1998) and scientific inquiry (AAAS, 1990; NRC, 1996, 2000). In particular, the *National Science Education Standards* (NRC, 1996) call for the centrality of inquiry in science learning:

> The *Standards* call for more than *science as a process*, in which students learn such skills as observing, inferring, and experimenting. Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. (p. 2)

The importance of inquiry in science learning has an established history (Bybee & DeBoer, 1993; Deboer, 1991; Trowbridge, 1990) dating back to Dewey (1910) and Schwab (1960,1966,1982,). However, the renewed emphasis on science inquiry reflects a distinct shift from *science as exploration and experiment* to *science as argument and explanation* (NRC, 2000). From the reform perspective, priority is given to evidence and the development and evaluation of scientific explanations. During all phases of the inquiry process, "students and teachers ought to ask *what counts?* What data do we keep? What data do we discard? What patterns exist in the data? Are these patterns appropriate for this inquiry? What explanations account for the patterns? Is one explanation better than another" (NRC, 2000)?

This approach to science learning presents new challenges for students engaged in authentic investigations of science phenomena. Loh and colleagues (1997) explain, "The complexity of open-ended investigations poses difficulties for groups of students who must continually negotiate plans and share understandings throughout an investigation" (p. 1). Not only do students struggle with organizing evidence and interpreting results, they often leave important questions unanswered when they are unable to make critical connections across various aspects of their investigations. The question for science educators becomes one of how to support learners as they participate in complex, data-rich investigations of scientific phenomena that require giving priority to evidence and constructing and evaluating scientific explanations? Furthermore, how do we support prospective and practicing teachers in orchestrating these types of learning opportunities for their students when most have not experienced learning science in this way themselves?

In this study, we explored the nature of two groups of prospective elementary teachers' scientific explanations within the context of a specially designed life science course. Both groups participated in long-term investigations of insect cultures in which they crafted testable questions based on observations, designed experiments, collected and interpreted data, constructed explanations and explored alternatives, and communicated their explanations to peers. Prior research by the investigators suggested that prospective teachers were likely to experience difficulties with various aspects of the experimental design, as well as the explanation building process (Haefner, 2001; Haefner & Zembal-Saul, 2001, 2002). In response to this, an intervention was developed for one of the groups using *Progress Portfolio*, a *generalized tool for articulation and reflection* developed at Northwestern University as part of the Supportive Inquiry Based Learning Environment (SIBLE) project (Loh et al., 1997). Differences across the two groups of prospective teachers' scientific explanations were examined. The research questions that guided this study were: (1) What is the nature of the scientific explanations developed by two groups of prospective elementary teachers as part of a specially designed science content course? (2) To what extent does *Progress Portfolio* influence the development of prospective elementary teachers' scientific explanations?

Literature Review

As mentioned previously, the renewed emphasis on scientific inquiry in contemporary reform shifts the focus to *science as argument and explanation* (NRC, 2000, p. 113). Practices, such as assessing alternatives, weighing evidence, interpreting texts, and evaluating the potential viability of scientific claims are all seen as essential components in constructing scientific arguments (Driver, Newton, & Osborne, 2000; Latour & Woolgar, 1986). Recently, various authors have called attention to the significance of argumentation to science education. For example, Jimenez-Aleixandre and colleagues (2000) explain, "Argumentation is particularly relevant in science education since a goal of scientific inquiry is the generation and justification of knowledge claims, beliefs and actions taken to understand nature" (p. 758). Other authors highlight the importance of argumentation for a variety of reasons. First, learners can experience scientists' practices that would situate knowledge in its original context (Brown, Collins, & Duguid, 1989), as well as provide opportunities to learn *about* science, not merely science concepts (Driver et al., 2000; Osborne, Erduran, Simon, & Monk, 2001). Second, learners' understandings and thinking can become more visible (Bell and Linn, 2000), representing a tool for assessment and self-assessment (Abell, Anderson, & Chezem, 2000; Sandoval & Reiser, 1997). Finally, argumentation can support learners in developing different ways of thinking (Kuhn, 1991, 1992, 1993) and facilitate science learning, taking into consideration the role of language, culture and social interaction in the process of knowledge construction (Pontecorvo, 1987).

As suggested in this last point, engaging in the construction of scientific arguments as a way of learning science is becoming more prominent in the literature (Driver et al., 2000; Kuhn, 1993; Linn, 2000; Newton, Driver, & Osborne, 1999). For example, Abell, Anderson and Chezem (2000) chronicled their experiences fostering science as argument and explanation with third-grade children engaged in inquiry-oriented instruction on sound. Students explored sound phenomena directly, then participated in discussions that required them to formulate and communicate evidence-based explanations. Although some ultimately students did not align with scientifically accepted ideas, the researchers concluded that the learning experience was valuable for all students because they had "opportunities to investigate, to invent sensible explanations, and to develop arguments in support of their explanations" (p.77).

To be clear, approaching science learning in this way is complex and fraught with difficulties. This kind of learning, as the literature illustrates, can be supported with the use of technology tools in science teaching and learning. Growing evidence from a number of studies supports the notion that software applications have the potential to engage students in scientific inquiry (Linn, 1991; Pea, 1993; Songer, 1993). This kind of software applications have been recently defined as software *scaffolds,* which enable learners to do more advanced activities and to engage in more advanced thinking and problem solving than they would do without such help (Bransford, Brown, & Cocking, 2000).

Scaffolding builds upon Vygotsky's model for the mechanism through which social interaction facilitates cognitive development resembles apprenticeship, in which a novice works closely with an expert in joint problem solving in the zone of proximal development (Rogoff, 1990). Specifically, Vygotsky (1978) defined the zone of proximal development as 'the distance between a child's actual developmental level as determined by independent through problem solving under adult guidance or in collaboration with more capable peers' (p. 86). A consideration of more recent work in technology-supported environments illustrates how the concept of scaffolding has expanded to include many new forms of support with increased responsibility for students (McLoughlin, 1999). For example, the computer software may allow students to organize and annotate a collection of evidence associated with a specific project, develop scientific arguments and share them with others (Bell, 1997), provide prompts for students' reflection on their ideas (Davis & Linn, 2000); engage students in inquiry-based investigations (Edelson, 2001) and support students' critical reflection and the development of evidence-based explanations (Land & Zembal-Saul, 2001; Loh et al., 1998).

A study by Bell (1997) investigated the use of *SenseMaker* in support of the construction of arguments using scientific evidence from the Web. As the researchers reported, *SenseMaker* allows small groups of students to organize and annotate a collection of evidence associated with a project that can then be shared with others. Approximately 180 middle school physical science students participated in this study and engaged in a project called 'How Far Does Light Go' where they were asked to construct two theoretical positions about the propagation of light and to interpret and critique a set of web-based multimedia evidence derived from both scientific and everyday sources. The findings of this study revealed that students' explanations had changed significantly from the beginning to the end of the project. As the researchers concluded, the students created arguments that were quite complex, personally relevant and scientific, which provides support to the notion that technology tools can support the development of students' argumentation skills.

In this study, prospective elementary teachers were engaged in an extended investigation on insects and required to construct evidence-based arguments. The use of *inquiry empowering technologies*[1] designed specifically to support science inquiry and scientific argumentation was fundamental to this work. For the purposes of this research, *scaffolding* is defined as supports that allow students to perform tasks that they would otherwise be unable to accomplish *and* to learn from that experience (i.e., improve performance on future, related tasks) (see Quintana, Reiser & Davis, 2002 and Reiser, 2001).

Despite the strong support for argumentation and the growing number of technology tools designed specifically to scaffold the process, argumentation practices have been rare in science classrooms (Newton, Driver & Osborne, 1999). Teachers' lack of pedagogical strategies to support students in engaging in argumentation, as well as the limited resources to assist teachers in doing so have been identified as the major barriers to the inclusion of argumentation in school science (Driver et al., 2000; Zeidler, 1997). It is unrealistic to expect teachers to adopt argumentation as a pedagogic practice to teach

[1] The phrase, *inquiry empowering technologies*, was coined by our colleague and mentor, Professor Vince Lunetta, to help us characterize the kinds computational tools that we select and integrate into science instruction. More specifically, *inquiry empowering technologies* refer to those computational tools that have the potential to enhance students' science learning as they engage in authentic, extended science investigations.

science if they do not develop more elaborated understandings of argumentation in the context of science learning. Such development is possible only if teachers engage in "the practice of constructive argumentation" (Zeidler, 1997), p. 485). However, virtually nothing is known about how science teachers (and in particular future science teachers) engage in argumentation as science learners to construct knowledge about the natural world and the practices of science (Zembal-Saul, et al., 2001; Newton et al., 1999). Therefore, the purpose of this study was to investigate the scientific explanations developed by two groups of prospective elementary teachers engaged in a specially designed science content course – one with the support of inquiry empowering technologies, the other without.

Context of Study

An applied life science course designed specifically for prospective elementary teachers, *Teaching with Insects*, provided the context for this study. *Teaching with Insects* is one of many courses, known as tracks, taken after successful completion of a half-semester prerequisite *Introduction to Entomology*. Other tracks have been developed for specific majors, such as turf grass management and forestry. All students spend the first half of the semester in the core course, *Introduction to Entomology*, and then enter a track that targets entomological applications in their specific field.

In the core course, prospective elementary teachers were introduced to basic entomology concepts such as internal and external anatomy, structural diversity, behavior, natural history and integrated pest management. In *Teaching with Insects*, prospective teachers were engaged in designing and conducting an original science investigation using insects that are commonly associated with teaching science in elementary schools. The prospective teachers worked in small groups, each with a different insect (Table 1). They were provided with instructional support during class meeting times, but the task was open-ended in that prospective teachers were encouraged to explore and investigate their own ideas.

The research associated with this course took place over two consecutive semesters. In the Spring 2001 semester, *Progress Portfolio* was incorporated into the *Teaching with Insects* course. All other aspects of the course remained consistent with the Fall 2000 semester, including the instructor. The *Progress Portfolio* tool was designed to promote reflective inquiry during learning in resource/data-rich environments (Loh et al., 1998). The software is a shareware application and was developed by researchers at Northwestern University. It is a software shell that allows teachers to craft templates that are used by students to guide them through complex tasks, progressively documenting the processes through which they engage in and complete tasks.

In the context of this study, the *Progress Portfolio* environment was tailored with the intention of assisting students in attending to data generated from their investigations

Table 1: Investigation Topics in *Teaching with Insects*

Semester	Insect Group	Investigation Topic
FA 2000	Mealworm	The influence of light and temperature on the rate of metamorphosis from the pupa stage to the adult beetle.
FA 2000	Milkweed Bug	The influence of light on the activity patterns of milkweed bugs.
FA 2000	Isopods*	Environmental influence on Isopod's choice of running or rolling following a stimulus.
FA 2000	Hissing Cockroach	The ratio of food consumption between adult roaches (seventh instar) and younger roaches that still undergo the molting process.
SP 2001	Mealworm	What conditions influence the rate at which mealworm beetles can right themselves when laying on their backs.
SP 2001	Milkweed Bug	How coloration influences mating patterns and choices of mating partners.
SP 2001	Isopods	Substrate preference of Isopods.
SP 2001	Bess Bug	The influence of physical appearance on social behavior.

*Although Isopods are not insects, they were an appropriate for use because non-insect arthropods were a topic of ENT 313 and they are familiar to children and classrooms.

and the explanations and conclusions they could construct from those data. The instructor-designed template included several pages that required the students to write their ideas and draw upon their knowledge of insects in order to explain what they were doing and/or learning. For example, the *Initial Ideas* (Appendix A) page required groups to write about and examine their observations and understandings for the purpose of generating original questions that could be investigated using their insect culture. On the *Research Design* (Appendix B) page, prospective teachers explained how the research design supported the research questions and on the *Results* (Appendix C) page, they discussed the results of the investigation in light of what they knew about the culture. Other pages were intended to support the interpretation of data for the purposes of generating scientific claims. Specifically, on the *Data* (Appendix D) page, the groups represented their data in graphical form and discussed the patterns that were visible. Then, on the *Explanations* (Appendix E) page, they used what they learned from their data to generate a series of claims about their insects. Each claim asked for supporting evidence and an associated justification statement of how the evidence supported the claim.

While the actual experiments took place out class, class time was devoted to learning about scientific experimentation. The course met two class periods per week (3 hours), and in each session focused on elements of scientific investigations and experimental design, such as making observations and crafting testable questions; collecting, analyzing and interpreting data; using evidence to construct data-based explanations and communicating results of research. In addition, each group was provided class time to document their work in *Progress Portfolio.*

Methods

This qualitative study was naturalistic and interpretive and reflected a design experiment (Brown, 1992) approach to examine the experiences of prospective elementary teachers in this innovative life science course. Design experiments attempt to create and simultaneously research innovative learning environments. Often, the settings are intact classrooms where students are encouraged to be part of a community of learners and engage in self-reflection and critical inquiry, and act as researchers responsible for defining their own expertise (Brown, 1992). In this study, prospective elementary teachers engaged in an original science investigation that they conceived, designed, and conducted as part of a collaborative inquiry group. Course instructors monitored the investigations, provided feedback, and offered support as needed.

Twenty-five prospective elementary teachers, ranging from freshman to seniors, participated in this study. Twenty-one were female and four were male. In total there were four small groups (2-4 students) each semester. It is important to note that there was a fifth group in the *Progress Portfolio* semester. However, they had difficulty with their design and were unable to collect any usable data. Unfortunately, without data they could not be expected to generate explanations for their experiment and were dropped from the study. Primary data sources included the prospective teachers' PowerPoint research presentations that were developed to communicate the research design and experimental results of the inquiry investigations and the *Progress Portfolio* artifacts (spring semester only). Transcripts of the videotaped research presentations were used as a secondary data source as needed for clarification of the PowerPoint artifact.

Data were analyzed by means of coding strategies consistent with constant comparative analysis. Codes were developed and refined using the research questions as a guide. Scientific explanations were identified in terms of the coherency between the questions, findings and explanations. An explanation was considered evidence-based if it was grounded in observations or data generated in the experiment. Explanations that were based on knowledge of insects but were not a condition tested in the study were not considered evidence-based.

Multiple researchers first coded data independently, and then collectively the codes were examined and renegotiated until all discrepancies were resolved. The first phase of analysis involved analyzing data within each semester group before making comparisons across semesters to identify emergent patterns in the nature of prospective teachers' scientific explanations. In the next phase of analysis, patterns were refined into descriptive themes that represented the influence of *Progress Portfolio* on prospective teachers' scientific explanations. Trustworthiness was developed through the use of multiple data sources, counterexamples to the assertions (Mathison, 1988; Maxwell, 1996) and collaborative modes of research (Merriam, 1998).

Results

The findings of this study are organized according to the two research questions. First, we describe the nature of the scientific explanations generated by prospective elementary teachers across two semesters, one without and one with the use of *Progress Portfolio*. The first section compares the explanations and discusses the patterns that emerged from each semester. The second section addresses the ways in which *Progress Portfolio* influenced the development of scientific explanations. Data from the second semester was used to examine how prospective teachers used *Progress Portfolio* during their long-term science investigations. The primary data sources for addressing these questions were the PowerPoint™ research presentations developed by each group of prospective elementary teachers and their *Progress Portfolios* (spring semester only).

Question 1: What is the nature of the scientific explanations developed by two groups of prospective elementary teachers as part of a specially designed science content course?

The findings of this study indicate substantial differences in the scientific explanations developed by prospective teachers who used *Progress Portfolio* and those who did not. More specifically, during the non-*Progress Portfolio* semester, none of the four groups of prospective teachers generated an evidence-based explanation for their experimental findings (Table 2). One group attempted to provide an explanation, but it was not grounded in data from their study and therefore was not considered evidence-based. In contrast, four groups who used *Progress Portfolio* generated explanations, three of which were grounded in experimental data.

Fall 2000: Non-*Progress Portfolio* Semester

In general, during the non-*Progress Portfolio* semester, the focus of the PowerPoint presentations seemed to be on reporting the results of the investigations, rather than attempting to develop an explanation for what was learned from the experiments. In addition, the non-*Progress Portfolio* group rarely applied their knowledge of insects to interpret the experimental findings. In fact, very few of the prospective teachers used their knowledge of insects to discuss the results of their investigations. For example, one group studied how light and temperature influenced the rate at which mealworm pupa metamorphosed into adult beetles. They hypothesized that under warm and dark conditions the process of metamorphosis would take the least amount of time. They presented their findings as "The light and dark experiment showed that the developing times are the same for both. We found the warmth caused the change to occur the most rapidly therefore making the heating pad situation the best overall environment (mealworm PowerPoint slide 11, 12/00)." The emphasis of this presentation was on reporting the results, rather than generating an explanation for why the pupa developed more quickly in warm conditions. In addition, the group was unable to apply their knowledge of insect development to interpret the findings, even after course instructors prompted them to consider the influence of temperature on insect life cycles in temperate regions.

The mealworm group's inability to connect their knowledge of insect development with environmental conditions was surprising because questions of this nature should have informed their research design. Unfortunately, after further probing by instructors, it was evident the experimental conditions were established out of convenience rather than knowledge of insects. More specifically, the design appeared to be random in that the selection of the warm temperature was based on the lowest setting

Table 2: Overview of explanations developed by prospective elementary teachers from the Fall 2000 (non-*Progress Portfolio*) and the Spring 20001 (*Progress Portfolio*) semesters.

Semester	**Insect Group**	**Nature of Explanation Provided**
FA 2000	Milkweed Bug	No explanation; statement of results, noted the acceptance or rejection of hypothesis
FA 2000	Hissing Cockroach	No explanation; statement of results, noted the acceptance or rejection of hypothesis
FA 2000	Mealworm	No explanation; statement of results, noted the acceptance or rejection of hypothesis
FA 2000	Isopods*	Attempted explanation but not evidence-based; statement of results, noted acceptance or rejection of hypothesis
SP 2001	Mealworm	Provided an evidence-based explanation; noted the acceptance or rejection of hypothesis
SP 2001	Milkweed Bug	Provided an evidence-based explanation as well as an alternative explanation for one of their experimental conditions; noted the acceptance or rejection of hypothesis
SP 2001	Bess Bug	Provided an evidence-based explanation
SP 2001	Isopods	Attempted an explanation but not evidence-based; noted the acceptance or rejection of hypothesis.

of the heating pad. Likewise, the temperature of their refrigerator determined the cold conditions. After all aspects of this investigation were examined it was clear the mealworm group not only failed to develop an evidence-based explanation, but their knowledge of insects was not used to inform any aspect of the investigation.

Another group investigated the effect of light on the activity patterns of milkweed bugs. They tested insect activity in constant light and constant dark and compared it to the normal the day/night pattern. They found that greater time periods of light resulted in increased insect activity and concluded, "Our data shows that the milkweed bug's activity is determined by light and dark rather than a circadian rhythm (milkweed bug PowerPoint slide13, 12/00)." Similar to the mealworm group, this presentation focused on stating a conclusion and the ultimate acceptance or rejection of the hypothesis, rather than generating an explanation for how or why the light influenced milkweed bug behavior. Moreover, they did not connect their findings to the normal seasonal changes in light patterns and the associated life cycles of insects.

The cockroach group examined whether adult roaches (7^{th} instar - no longer molting) ate more food than smaller, younger roaches. This question arose because they noticed young roaches often congregated around the food supply. They monitored food consumption over time between large and small roaches and presented their results.

> As one can see by looking at the difference in color [referring to a pie chart], the younger roaches consumed a higher percentage [of food] than the older roaches did. This chart supports our hypothesis in which we stated that the younger roaches will consume more food than the older roaches (cockroach PowerPoint slide17, 12/00).

Similar to the milkweed bug group, the roach group focused primarily on reporting results and offered no explanation for why they thought the younger roaches ate more. However, they did use their knowledge of the molting process to inform the development of future questions that emerged from their study. More specifically, they questioned whether roaches ate more while molting. This is interesting in that their knowledge of the molting process should have been helpful for them to explain the findings of this study, rather than simply inform the next one. Even though this group of prospective teachers used their knowledge of insects for inform areas for future research, they were unable to apply that knowledge for the purposes of interpreting experimental results.

The Isopod group was the only group of prospective teachers from the non-*Progress Portfolio* semester who explicitly attempted to provide an explanation for their experimental findings. They investigated the role of environmental factors, such as the presence or absence of cover, on an Isopod's decision to run or roll in response to a stimulus. This group worked with a common Isopod, the roly poly, which has the ability to roll itself into a ball. They concluded that environmental factors did not influence the Isopod's decision to run or roll. Rather, they stated, "It appears that the severity or type of stimulation given is more likely to be the determining factor (Isopod PowerPoint slide 20, 12/00)." While this was an attempt at an explanation of the findings it was disconnected from their study, which focused on specific environmental attributes. The explanation was based on general observations of Isopod behavior and was not a condition of their experiment. Therefore, due to the lack of experimental evidence, the explanation was not considered evidence-based.

It is important to note that while the Isopod group was the only group to attempt an explanation, they were also the only prospective teachers who were able to respond to questions from course instructors and use their knowledge of Isopods to further develop their ideas. For example, when pushed by very specific questions about why they thought the type of stimulus was important to Isopod behavior, they were able to draw upon their knowledge of the natural environment in which Isopods are found. For example, Brian said,

> I think it could do with where they live because they like to be in the dirt or under leaves. They are being subjected to a lot of minor stimulation like if they are under leaves. These environmental changes happen as new leaves or twigs fall, but these don't necessarily threaten them. They may just want to move away. They don't really need to roll up. Maybe it is not just a natural thing they do (research presentation transcript, 12/00).

While this was more conjecture than explanation, it was an attempt to connect their knowledge of Isopods with what happened in their study. None of the other groups were able to do this, even after direct prompts from course instructors.

Spring 2001: Progress Portfolio Semester

In contrast, the following semester four groups of prospective teachers who used *Progress Portfolio* developed an explanation for the results of their long-term science investigations. Three out of the four groups grounded their explanations in experimental evidence and one of the four groups also offered an alternative explanation. In addition, while some attempts were more appropriate than others, all groups explicitly used their knowledge of insects to make sense of their experimental results. For example, during the *Progress Portfolio* semester the mealworm group examined the conditions under which a beetle placed on its back could right itself in the shortest time. They tested three different conditions (a flat sheet of paper, bed of oatmeal, and the presence of other beetles) and presented their findings as,

> From this data, we have learned that is virtually impossible, within a minute for the beetles to get up without the use of their surroundings, whether it is the oatmeal or other beetles helping them. With no surrounding, no beetles were able to turn over. With the oatmeal, on average it took less time than when they were with two other beetles (mealworm PowerPoint slide 8, 5/01)

Like the non-*Progress Portfolio* groups, this statement focused on reporting the results. However, unlike the previous semester, this group included a slide entitled *explanations* that said,

> Mealworm beetles need to have something in order to get right side up after being on their back. We can explain this by considering that in the first set of trials when the beetle was alone on a piece of paper, it was unable to get up within one minute. We can further support this by considering the hardened elytra on their back and their short legs contributing to the fact that they experienced difficulty in getting up (mealworm PowerPoint slide 14, 5/01).

In this example, the prospective teachers used their knowledge of insects to interpret the results of their experiment. More specifically, they used the physical characteristics and structure of mealworm beetles to explain why the insect could not turn itself over on a hard surface. This group also included another slide that offered an explanation for a test that had one beetle on its back while in the presence of two other right-side-up beetles. They stated,

> Mealworm beetles are not social insects. This can be explained in that there was a large range in result times in our third set of trials with two right side up beetles. Because they made no effort to help the beetle struggling on its back, if the beetle made it to its feet by chance, it was due to another beetle randomly passing by in its explorations (mealworm PowerPoint slide 15, 5/01).

While this explanation is rather underdeveloped, the group still attempted to explain this part of the experiment. Moreover, they once again tried to ground the explanations in what they knew about insects. In this case, the lack of social interaction between mealworm beetles was used to explain why the other beetles did not help the one in distress. In the previous semester, the prospective teachers had difficulty applying their knowledge of insects to explain their findings.

The investigation of the milkweed bug group was more complex in that they studied the mating habits of milkweed bugs. Specifically, they wanted to investigate the influence of light, as well as the role individual coloration played in mate selection. The results of the light test were presented as,

> Our experiment shows that when kept in constant daylight, the insects only mated 3 times! When kept on a normal 24-hour cycle, the insects mated 13 times! Based on our conclusions, we decided that our hypothesis is correct. The insects kept in constant daylight mated much less frequently that those kept on a normal 24-hour cycle (milkweed bug PowerPoint slide 11, 5/01).

This part of the presentation was similar to those in the non-*Progress Portfolio* semester in that they simply reported the findings of the experiment and did not try to explain the influence of light on mating behavior. However, when they presented the results of the color experiment, there was a different focus.

To test the influence of color, the prospective teachers painted several of the individual bugs different colors and measured how often they were selected as mates. They conducted several trials and found the results differed depending on whether the painted insects were male or female. While color did not appear to influence the mating frequency of males, painted females were selected as mates less often than unpainted females. To explain this discrepancy they stated,

> Regarding the inconsistent results of the paint experiment, there were a few discrepancies. First, there is the question of which sex chooses the mating partner. This could definitely explain the difference between the two experiments. There is also the presence of pheromones that could have had an affect on the results. Since the paint was present, this could have thrown off their innate sense of smell (milkweed PowerPoint slide 19, 5/01).

It is evident that the prospective teachers in this group used their knowledge of insects to generate explanations for the results of this part of the investigation. The knowledge that one sex is often responsible for mate selection enabled them to explain why there was little difference between the number of times painted and unpainted males were chosen as mates. Moreover, they used their understanding of how insects use pheromones to generate an alternative explanation for their findings. This is noteworthy in none of the other prospective teachers explored alternatives when generating explanations. The nature of these explanations suggest this group was able to make connections between their experimental results and what they understood about insect characteristics and mating behaviors.

The third group of prospective teachers examined the social interaction of bess bugs. More specifically, they wanted to test whether physical appearance would influence their tendency to "clump" together in small groups. Rather than test color, this group painted patterns, such as eyespots, on the exoskeleton of the beetles. The results of the study suggested that patterns painted on their backs did not deter the insects from congregating in small groups. In fact, the data showed a slight increase in clumping behavior after painting. In their discussion, while they did not directly address the issue of the slight increase in clumping behavior, they offered the following explanation.

> The bess bugs liked the same wood and their eating of that wood caused a constant clumping around that area. The bess bugs tended to clump near the moisture supply in the sponge and paper towels. The bugs tend to clump in dark spaces in the environment [and] the dark spaces are limited. Therefore they would be near each other for reasons other [than] their social behavior (bess bug PowerPoint slide 14, 5/01).

This explanation is somewhat different that those of the previous *Progress Portfolio* groups because it is not focused on explaining the data collected in the study. Like the Isopod group from the non-*Progress Portfolio* semester, this explanation was not based on an explicit condition tested in the experiments. In other words, this group did not directly test the influence of environmental features on insect behavior. However, this explanation was grounded in observations made during the study, therefore it was still considered evidence-based. In addition, even though it was simplistic and somewhat underdeveloped, the explanations were connected to their knowledge of the insect's environmental needs. The bess bug group clearly recognized that resources found in the habitat could have accounted for the clumping behavior.

The fourth group of prospective teachers examined the environmental preferences of Isopods. They tested four different substrates and measured the number of Isopods present in each one at certain times. The results indicated the Isopods preferred wood chips over sand, soil and clay. In their presentation, the group included a slide entitled *Discussion of Results* where they stated, " On average, the [Isopods] were found in the wood substrate. The [Isopods] could have preferred the wood because they are adapted to it (Isopod PowerPoint slide 8, 5/01)." Like the previous groups, the prospective teachers attempted to provide an explanation for their experimental findings that was grounded in their knowledge of Isopods. In particular, they knew that Isopods are commonly found in or around decaying wood and used this information to support their explanation. However, Isopod adaptations were not a condition tested in the study. As a result, there was no experimental evidence to support the explanation.

Overall, when comparing the nature of the explanations developed across the two semesters, the prospective teachers who used *Progress Portfolio* were more inclined to uses their knowledge base of insects to generate explanations for their experimental findings. To identify the role *Progress Portfolio* played in the development of prospective teachers' explanations the ways in which they addressed the prompts provided in the template, as well as how they used it to construct their PowerPoint research presentations, were examined. The *Progress Portfolio* template enabled the prospective teachers to track their developing ideas and understandings as they progressed through an original science investigation. The purpose of the scaffolds in *Progress Portfolio* was to structure the task of using their knowledge of insects to examine what they were learning from the investigations in order to develop and articulate an evidence-based explanation for the experimental findings.

Question 2: To what extent does *Progress Portfolio* influence the development of prospective elementary teachers' scientific explanations?

The findings suggest that *Progress Portfolio* supported prospective teachers in developing scientific explanations. More specifically, the scaffolds in *Progress Portfolio* were useful for the purpose of making connections between an existing knowledge base of insects and what was being learned from the investigations. However, the kinds of explanations they developed seemed to be related to the nature of the prospective teachers prior understandings about insects. More specifically, those who demonstrated a more robust knowledge of insects and concepts associated with the focus of their research produced richer, more appropriate explanations that were often grounded in experimental evidence. Conversely, those who did not demonstrate understandings of related important concepts often generated either no explanation at all or explanations that were limited and underdeveloped.

Even though all groups who used *Progress Portfolio* used their knowledge of insects to develop an explanation for at least one of their experimental results, the nature of those explanations was different in terms of consistency and depth. For example, the milkweed group, who tested the influence of light and individual coloration on mating behaviors, had a solid evidence-based explanation for the color test, yet they completely failed to address the results of the light experiment. Examination of their *Progress Portfolio* revealed evidence of their knowledge of insect mating behaviors before they designed the investigation (Appendix A). They explicitly addressed general observations of mating activity such as frequency and nesting habits, as well as specific characteristics of courtship behavior. That knowledge later served to inform and support the explanation developed for this part of the investigation. However, with regard to the light experiment, there was no evidence of prior understandings of how light influenced insect behavior. In fact, at no time in *Progress Portfolio* did they write about the role of light in the milkweed bug life cycle. Consequently, this group did not make explicit connections between what they learned from this part of their investigation and what they already knew about their insect, nor they did not develop an explanation for this experiment.

Similarly, in the research presentation, the mealworm group provided a solid explanation for why the mealworm beetle could not right itself when lying on its back on a hard surface. In the *Progress Portfolio,* they articulated their understanding of the physical features that determined its taxonomic classification, specifically the hardened forewings that cover and protect the back of the insect (Appendix F). When generating their explanation, they used that knowledge to explain the results of the first experiment. However, the explanation they provided for why the insect could not right itself while in the presence of other beetles was somewhat limited. They stated the other mealworm beetles did not help the one on its back because they are not social insects. Examination of their *Progress Portfolio* revealed very little in terms of their understandings of social behavior. In fact, while they made early observations of mealworms lying on their backs (Appendix F), they never mentioned any kind of social network between the insects that would have informed this part of the investigation.

The explanations of the final two groups were somewhat different in that they were not as developed or supported. The bess bug group tested the effect of a change in appearance on the insects' tendency to clump in small groups. Their results indicated a very small increase in the behavior and the group concluded the change in appearance did not deter the insects from clumping. While they explained why they thought the change in appearance did not deter the behavior, they did not address the slight increase illustrated in the data. Moreover, examination of the *Progress Portfolio* revealed that the group had observed behaviors that were similar to those observed during the investigation and later used to explain the results (Appendix G). In the *Progress Portfolio*, they wrote about how the insects liked to be in the dark and liked to eat the same piece of wood. Although the prospective teachers did use their knowledge and experience with the insects to explain the results, it was rather basic and superficial. However, this was also characteristic of the understandings they represented in *Progress Portfolio*. This group did not demonstrate a complex understanding of insect sensory functions that could have influenced how the individual painted insect was perceived, nor did they address the social network and structure of bess bug interactions. Consequently they were unable to make sense of the increase in clumping behavior. As a result, it appears they used the only understandings they could to develop an explanation for the results of their investigation.

The Isopod group was similar in that their entire investigation was not very complex. They did a simple substrate preference test and concluded that Isopods preferred wood chips to sand, soil and clay. Their explanation for this finding was based on their knowledge that wood is part of their diet. Their *Progress Portfolio* suggested very limited knowledge of their insect in general. In fact, the only information they provided about Isopods was general observations of their physical features and characteristics of their natural habitat (Appendix H). There was no evidence they had understandings of concepts that would have been useful for explaining their results such as Isopods' ecological niche, nutritional needs, and the composition and structure of the particular substrates. Therefore, like the previous group, these prospective teachers used the only knowledge of the Isopods they had to develop an explanation for their experimental findings.

When examining the ways in which *Progress Portfolio* assisted the development of evidence-based explanations, a related issue emerged with regard to their understandings of data and evidence. Many of the prospective teachers had difficulty representing their data in ways that were powerful (Appendix I). Consequently, this may have limited their ability to look for and interpret patterns. This could account for some of the inconsistency with which they used their data to construct explanations, as well as their need to go beyond the data to look for explanations. Moreover, it was clear that even the prospective teachers who constructed an evidence-based explanation were not always certain what counted as evidence. For example, on the *Explanations* page, the prospective teachers had to develop a series of claims about their insects. Each claim had to be supported with evidence and have an associated statement that justified the evidence. Many of the groups had difficulty with that task. In many instances, the claim, evidence and justification statements lack coherence and were sometimes contradictory. For example, the milkweed bug group, who was able to generate an evidence-based explanation for their research presentation, made the following claims:

> *Claim:* Milkweed Bugs use their sense of smell, or innate pheromones, to choose their mate.
> *Evidence:* When we initially paired the insects after applying the paint, their mating patterns were disrupted. Overtime, after the smell of the paint wore off, their overall mating patterns returned to normal.
> *Justification:* This occurred because as we previously learned, insects use pheromones to search for others like them and ultimately find a mating partner
> (*Explanations* page, milkweed bug *Progress Portfolio*, 5/01)

This claim is a fair attempt at explaining a pattern in the data. However, the claim is not entirely appropriate in that they really tested appearance, not smell, and in reality had no evidence of the presence of pheromones. Certainly, paint could disrupt the detection of pheromones, but the presence of pheromones was not a condition tested in their investigation.

Similarly, the bess bug group, who went beyond their experimental data to construct an explanation for their findings, developed the following claim:

> *Claim*: Paint does not effect the Bess Bug's social behavior.
> *Evidence*: After painting the Bess Bugs, there was still clumping. In fact, there was an increase in clumping.
> *Justification*: The paint was added to their outer shell and through observation there was no negative influence.
> (*Explanations* page, bess bug *Progress Portfolio*, 5/01)

While this claim was an accurate representation of what they presented as their research findings, what they used as evidence was contradictory to the claim. Moreover, the justification statement did not justify how the evidence was intended to support the claim.

In general, the milkweed bug and bess bug groups had difficulty constructing coherent claim, evidence and justification statements, and the mealworm group had difficulty developing them consistently. They presented the following two claims:

> *Claim*: Mealworm beetles need to have something in order to get right side up after being on their back.

Evidence: In the first set of trials when the beetle was alone on a piece of paper, it was unable to get up within a minute.
Justification: The hardened elytra on their back and their short legs contributed to the fact that they experienced difficulty in getting up.

Claim: Mealworm beetles are not social insects.
Evidence: There was a large range in result times in our third set of trials with two right side up beetles.
Justification: They made no effort to help the beetle struggling on its back. If the beetle made it to its feet by chance, it was due to another beetle passing by in its explorations.
(*Explanations* page, mealworm *Progress Portfolio*, 5/01).

In this example, the first claim was supported by experimental evidence and justified using their knowledge of insect characteristics. The sequence itself was one of the strongest in terms of coherence and appropriateness. However, the second example was completely disconnected and illustrated a lack of understanding of social behavior. In Entomology, social behavior suggests a complex network of interactions and community structure. This group seems to be using the term in colloquial sense rather than its true meaning. Moreover, the relationship between the claim and what they provide as evidence is unclear. They tried to use a pattern in their data as evidence for lack of social behavior, but social behavior was not the focus of their investigation. These findings suggest the scaffolds in *Progress Portfolio* that were intended to support the interpretation of data for the purposes of generating scientific claims were not as useful for supporting argument development. The inconsistent ways in which the prospective teachers in this study were able to use data in powerful ways suggests their understandings of what counted as evidence were fragile and limited. This finding draws attention to the complexity of supporting the development of prospective teachers' understandings of data and evidence.

Discussion

This study on supporting prospective elementary teachers in developing scientific explanations illustrates *Progress Portfolio* can assist prospective teachers in developing explanations that are grounded in experimental data. Without the use of *Progress Portfolio*, the prospective elementary teachers in this study were unable to construct evidence-based explanations for the results of their inquiry investigations. This finding is important since the ability to develop scientific claims and craft explanations is a central feature of scientific inquiry (NRC, 2000). Specifically, reform documents (i.e, *National Science Education Standards*) emphasize the engagement of learners in the construction and communication of scientific claims and explanations, which also supports gaining an understanding of how scientists conduct their work (NRC, 1996, 2000). Driver, Newton and Osborne (2000) refer to this process as enculturation into science where students not only hear explanations being given to them by experts, but also practice using the ideas themselves and develop an understanding of scientific practices and ways of thinking. Engaging in the development of arguments supports students in gaining understandings about scientists' work and the nature of science, as well as assists in the development of critical attitudes (Popper, 1963), knowledge (Quinn, 1997) and argumentation skills that could be used in social life situations (Newton et al., 1999; Patronis, Potari, & Spiliotopoulou, 1999).

Furthermore, the fact that the participants were able to develop evidence-based explanations with the use of *Progress Portfolio* is important given the emphasis on the role of evidence in explanation development (NRC, 1996, 2000) and the literature that suggests the complexities of understanding experimentation (Schauble, Klopfer, & Raghavan, 1991) and evidence (Gott & Duggan, 1996; Millar, Lubben, Gott, & Duggan, 1994). Gott and Duggan (1996) proposed that while open-ended investigations offer an advantage for learners, understanding the actual concept of evidence requires more than just the skills of doing the task. Moreover, it has been suggested that a knowledge base for understanding evidence must be taught and not assumed it will be acquired through experience (Millar et al., 1994). The findings of this study are consistent with the difficulties of understanding evidence outlined in the literature. While *Progress Portfolio* was useful for making connections between data and the development of explanations, the understandings that prospective teachers had of what constituted evidence remained fragile.

Progress Portfolio was designed to provide a workspace for learners to document their questions and understandings, manage their data and analyses, and communicate about and reflect upon their investigation (Loh et al., 1998). In this study, the tool was useful for structuring and tracking the progress of prospective elementary teachers as they engaged in an original inquiry investigation. Moreover it supported reflection on what the prospective teachers were learning from the experiments in light of what they knew about insects. Among the benefits was that the template made important aspects of conducting investigations explicit, including the role of scientific explanations. For many of the prospective teachers in this study, this was their first experience engaging in an original science investigation and the structure provided by *Progress Portfolio* supported the coherence of their experimental design and the management of their data. A strength of *Progress Portfolio* is the ability to focus students on the typically invisible aspects of the inquiry process and enable them to track of their progress as they engage in long-term investigations (Loh et al., 1997; Loh et al., 1998). Previous research on the experiences associated with this particular course without the use of *Progress Portfolio* revealed instances in which prospective teachers struggled to manage large amounts of data and interpret the experimental findings (Haefner, 2001; Haefner & Zembal-Saul, 2001, 2002). Research on children's experimentation indicate that with experience, children's reasoning processes improve (Schauble et al., 1991) and they get better at conducting experiments (Millar et al., 1994). Perhaps with the use of technology tools, such as *Progress Portfolio*, the open-ended process of engaging in long-term inquiry investigations can be supported in ways that progressively develop understandings of experimentation.

The findings of this study also suggest that the scaffolds provided by *Progress Portfolio* were useful for the purpose of making connections between an existing knowledge base of insects and what was being learned from the investigations. Without the use of *Progress Portfolio*, the students primarily reported results rather than develop explanations for their experimental findings. The scaffolds provided by the prompts enabled students to focus and clarify their thinking and make connections with their existing understandings of insects. When students failed to articulate their understandings, they were unable to make connections between their ideas and what they learned from the investigations. In a study on scaffolding students' knowledge integration, Davis and Linn (2000) investigated how students responded to specific prompts and the ways in which the prompts encouraged reflection. They reported that particular prompts encouraged students to reflect on their own understandings and provided scaffolding that assisted students thinking about their goals and progress on projects. However, the authors noted, "by articulating their plans, thoughts, and confusions, they are better able to note areas in which their own understanding is lacking and to engage in knowledge integration. But by not articulating their ideas, they forego opportunities to integrate their knowledge (p. 835)." In this study, the opportunity to make their thinking visible (Davis & Linn, 2000; Linn, 2000) emerged as an important step toward explanation development.

This research also sheds light on the utility of *Progress Portfolio* as a tool for supporting reflection. Given the emphasis on more authentic learning experiences in which students are engaged in extended inquiries (Council, 1996), students must do more than develop questions and pursue unstructured explorations (Loh et al., 1998). This more open-ended approach to science learning requires a greater level of self-directed learning that requires students to reflect upon their understandings in light of new information and experiences. Davis and Linn (2000) suggest reflection supports developing more coherent, integrated understandings by motivating students revisit, test and restructure the connections among their existing ideas. However, learners may not always reflect upon their experiences and generate new understandings in ways that are anticipated (Brickhouse, 1994). Therefore they must be able to organize, evaluate and monitor their progress as they develop these practices.

Progress Portfolio is one way to support students' reflective inquiry by coordinating and documenting their inquiry processes (Loh et al., 1997). In this study, the scaffolds provided by the *Progress Portfolio* template assisted explanation development by supporting reflection on what was being learned from the investigation in light of what was known about insects. However, the kinds of explanations that prospective teachers' developed were closely connected to the nature of their knowledge base of insects. When the prospective teachers were unable to connect the results of their experiments with their existing knowledge of insects, the explanations were underdeveloped or omitted. Loh and colleagues (1997) suggest students who are unable to make connections across aspects of investigations will leave important questions unanswered. The findings of this study support previous research by Land and Zembal-

Saul (2001) on scaffolding reflection and explanation development using *Progress Portfolio*. In their study, prospective teachers with limited and fragmented background knowledge had difficulty generating ongoing explanations in response to prompts by *Progress Portfolio*. Similarly, in a study on developing theories of light and shadows, Brickhouse (1994) reported that children's ideas were useful in helping them make sense of observations of light, but not of shadows. She attributed these findings to the children's limited understandings of shadows and the lack of an explanatory framework to organize and interpret the observations of shadows. Findings such as these are important and have implications for the kinds of inquiry-based learning experiences we design for students.

Conclusions & Implications

The findings of this study on the development of scientific explanations suggest that technology tools such as *Progress Portfolio* can assist prospective elementary teachers in developing evidence-based explanations. While understandings of evidence emerged as fragile, the tool was useful in supporting reflection and facilitated connections between what was being learning from the investigations and their existing knowledge of insects. In addition, the *Progress Portfolio* template made important elements of experimentation explicit, including the role of evidence and explanation. While it is important to examine the nature of scientific explanations, this research also provides implications for science teacher educators as we strive to support the development of elementary teachers who are prepared to teach children in the vision of current reform.

While this research suggests *Progress Portfolio* can support the experience of engaging in a long-term science investigation, a serious limitation is that most prospective teachers have not had opportunities to engage in science inquiry as learners, not to mention develop understandings of the nature of scientific knowledge and the purposes of scientific investigations (Smith & Anderson, 1999). This is problematic given research that has shown prospective teachers often have limited understandings of their subject matter (Ball, 1990; Ball & McDairmid, 1990; Cochran & Jones, 1998) and the current emphasis on science inquiry and the shift to science as argument and explanation (NRC, 2000).

The findings of this study suggest a close relationship between knowledge of insects and the kinds of explanations developed for investigations using insects. Given that contemporary reform efforts in science education (NRC, 1996) emphasize the content and processes of science, there is a compelling need to help prospective teachers develop more robust understandings of the discipline. Thus, the first implication is the need for prospective teachers to develop rich and integrated understandings of subject matter. Research has shown that specially designed content courses can assist prospective teachers in developing more appropriate understandings of science and science inquiry (Haefner, 2001; Haefner & Zembal-Saul, 2001, 2002). However, understanding the goals and purposes of experimentation requires more than one experience engaging in scientific investigations (Millar et al., 1994; Schauble et al., 1991).

A second implication of this work is related to the kinds of learning experiences we provide for prospective teachers. This research suggests that the development of explanations was supported when connections could be made between a knowledge base for insects and experimental results. Therefore, that element of reflection on learning in light of what is already understood emerged as an important consideration for supporting explanation development. When designing opportunities to learn science as inquiry, we need consider what knowledge learners bring to the experience. Engaging students in science investigations that focus on concepts of which they have very little understanding could stand to hinder the interpretation of data and understandings of experimental evidence.

Similarly, when using technology tools such as *Progress Portfolio* to structure the task of explanation development, consideration needs to be given to the ways in which data are represented and the opportunities for learners to make explicit the understandings on which they are drawing. Scaffolding the process of explanation development should support the representation of data in powerful ways and facilitate the examination of what counts as evidence. Learners need opportunities to articulate and reflect upon developing understandings, question the data, and identify appropriate patterns that lead to the development of explanations (NRC, 2000).

Finally, while the findings of this study are encouraging, this research revealed discrepancies in the ways in which the prospective teachers engaged in the development of explanations. An important limitation of this study is that we do not know the processes the students went through while developing their *Progress Portfolios* and PowerPoint research presentations. While *Progress Portfolio* has been shown to support collaborative reflection and have the potential to support communication as students negotiate the articulation of ideas (Loh, et al., 1997), data on these elements were missing from this study. Therefore more research in this area is certainly warranted. Understandings of group dynamics, student interactions, and the nature of their conversations would offer insight into the experience of planning, conducting and interpreting the results of an original inquiry investigation. Moreover, awareness of how they engage in this process could inform the restructuring of the technology scaffolds so to better assist data interpretation and argument development.

In closing, this research raises questions associated with supporting students' scientific inquiry. The prospective teachers in this study held fragile understandings of evidence and explanation, and their associated role in scientific arguments. This could be related to their limited understandings of data and data representation. It is not uncommon for the prospective elementary teachers enrolled in this course to struggle with how to construct graphs of the data. This is particularly problematic if engaging in inquiry is to become a prominent part of science learning (NRC, 1996; 2000). If prospective elementary teachers cannot represent data in powerful ways, how can they use it to generate appropriate scientific claims and arguments? More importantly, if they hold limited understandings of important elements of inquiry, can we realistically expect them to support children's science inquiry? Clearly more research in this area is needed to offer insight into the nature of prospective teachers understandings of data representation and to determine the kinds of experiences that assist developing understandings of evidence and argumentation in science.

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Appendix A. Sample *Initial Ideas* page from the milkweed bug's *Progress Portfolio*.

Inquiry Project

Culture: Milkweed Bug

Group Members: Keri, Bonnie, Jenna

Prior Knowledge

The prior knowledge that we had about the Milkweed bug is that they:

-primarily feed on the Milkweed plant providing them with defense mechanisms such as bad taste and aposomatic coloration.

-mate end to end.

-may mate as long as a half of an hour up to a few days.

-have distinguishable coloration on the ventral side of their abdomen. Females have a single black line accompanied with two

Observations

-They mate ALL the time! Everytime we look into our culture, there are always "couples" present.

-Once they have mated, they tend to lay their eggs on the wet cotton.

-One of the most obvious features of these insects is the fact they rub their legs together quite often.

-When we first obtained them, they usually stayed together in a group while they positioned themselves on the lid of the container.

-After a few days, they started becoming more familiar with their new environment and broke off into smaller groups, sometimes roaming the cage by themselves.

Based on what you know about your insect and what you have observed in your cultures, what assumptions can you make about your insect?

Well, we have decided that we don't have the most exciting insect, but we still got the opportunity to make many assumptions regarding our insect's behavior. After observing them laying their eggs on the cotton, we assumed that they chose this "nest" due to the fact that they usually lay their eggs on the milkweed, which is very similar to the cotton. knowing that they like to mate end to end, we were able to observe exactly when they were mating. From our observations, we have concluded that they like to mate several times throughout the week. We have yet to discover what exactly influences their mating ritual, but we decided to further investigate this behavior. Due

Appendix B. Sample *Research Design* page from the bess bug group's *Progress Portfolio.*

Page : Research Design Page 2 04/29/01, 7:49:4

Research Design

Questions:

Do Bess Bugs clump due to physical appearance?

Hypothesis:

We think they are going to clump no matter their appearance due to their social instinct.

Materials:

4 Bess Bugs
2 containers
Non Toxic Paint
Journal

Variables

Define clumping--
clumping- 2 or more bess bugs within a one inch radius from each other.
color blindness-
paint bess bugs with

#Trials and participants

1 Trial involving 4 paticipants--observing 2 times a day

Procedures

1. Take observations on bess bug cultures and clumping. Record in group journal.
2. Place the 4 bess bugs into one new container.
3. Paint two of the four bugs with non-toxic craft paint. Let them dry. Replace them in the container.
4. Observe them daily, for five minutes at a time, morning and night. Record findings in the group journal.
5. Repeat for four days.

How do your procedures support your research questions?

Our procedures test our research question because it is a way to challenge their clumping instinct. They have a tendency in their containers now to stay near each other most of the time and we wanted to see if modifications resulted in the same behavior. The patterned paint modifies their apperance. This may result in nonclumping.

Page Type : Research Design

Appendix C. Sample *Results* page from the milkweed bug's *Progress Portfolio*.

Page : Results Page 19

Results

Results

Concerning the painted females and unpainted females, there are hopeful results. The control male chose the unpainted female 4 times and the painted female only 2 times! Throughout the three trials, the number fluctuates a bit, but still gives us concrete, possibly confirming evidence, that the paint could have had an affect on their mating patterns. Therefore, the color of the female may have a role in the male's choice of a mate. However, the results for the painted male and unpainted male were not too satisfying. The control female chose the unpainted male 4 times and the painted male 5 times. This obviously has a twisting affect on our

Issues that influenced the results

There was one major factor that could have influenced our results. One of the first factors that we tried to distinguish was the question of whether the male chooses the mate or the female instigates the mating process. From our results, we have come to realize that the male is probably the dominant partner and is the insect that makes the first move and chooses to mate. As seen, the control male chose the unpainted female twice as much as the painted one. This shows that the paint did have an affect on the Milkweed Bug's mating rituals because the male was not in favor of the painted female. In addition, our results show that the painted male was chosen

Discrepancies between what happened in this experiment and what you know about your insect (prior knowledge).

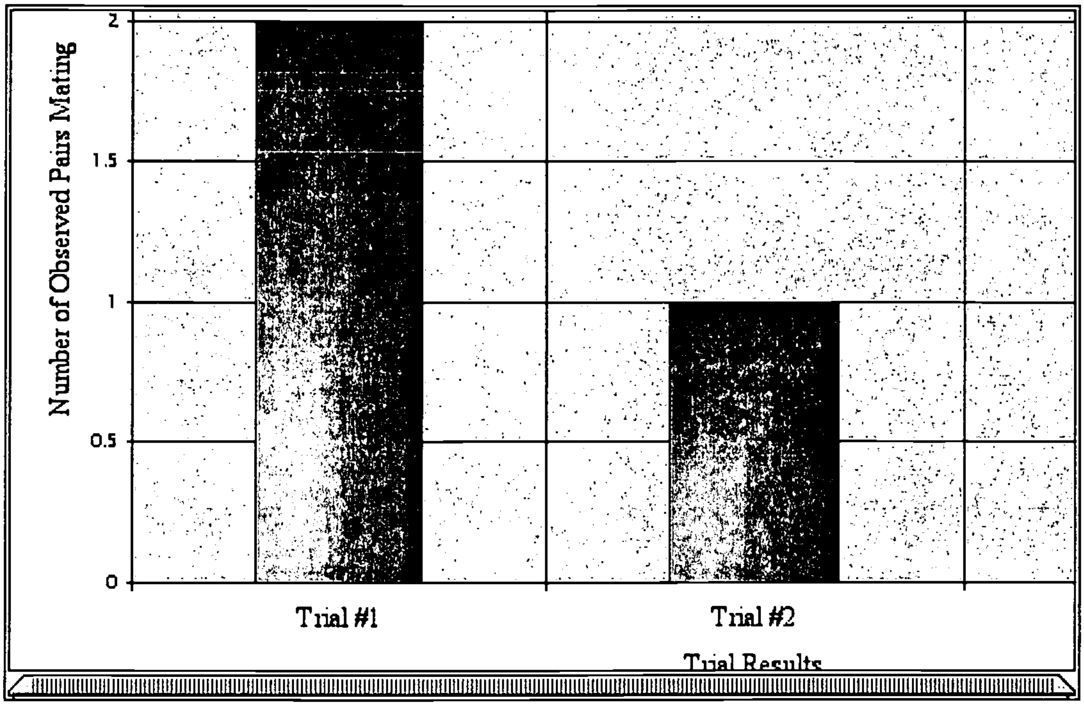
Throughout the course of our experiment, the behaviors we observed followed closely with our prior knowledge. Not only did they mate at the usual frequency, but they could also be affected by the smell of the paint. This relates back to their use of pheromones to detect other Milkweed Bugs, which we learned earlier.

Page Type : Results

Appendix D. Sample *Data* page from the milkweed bug's *Progress Portfolio*.

Page : Data Page 17

Data



What patterns are visible in this data?

As seen, there is a slight difference in the number of times the painted female was chosen as a mate in comparison with the unpainted female. We concluded that this that is perhaps due to the presence of the paint on the female's visible region. Since the control male mated with the unpainted female twice as much as the painted female, we have decided that the paint caused a definite pattern in the data. On the other hand, there is hardly a difference in the number of times a painted male was chosen as a mate in comparison with the unpainted male. Unfortunately, there seems to be no visible pattern regarding this particular data.

Page Type: Data

Appendix E. Sample *Explanations* page from the mealworm group's *Progress Portfolio*.

Explanations

Based on your experiment, what claims can you make about your insect?

Claim: Mealworm beetles need to have something in order to get right side up after being on their back.

Evidence: In the first set of trials when the beetle was alone on a piece of paper, it was unable to get up within a minute.

Justification: The hardened elytra on their back and their short legs contributed to the fact that they experienced difficulty in getting up.

Claim: Mealworm beetles are not social insects.

Evidence: There was a large range in result times in our third set of trials with two right side up beetles.

Justification: They made no effort to help the beetle struggling on its back. If the beetle made it to its feet by chance, it was due to another beetle passing by in its explorations.

Appendix F. Sample *Initial Ideas* page from the mealworm group's *Progress Portfolio.*

Inquiry Project

Culture: Mealworm Beetles
Group Members: Alice, Brenda, Marla

Prior Knowledge

*Prefer grain for food
*Grain pest
*Prefer dark areas
*Dry areas
*Complete metamorphosis
*Moisture from apples and potatoes
*mealworms used for fish bait and other animal foods
*male and female indistinguishable
*Coleoptera-6 legs, 3 body regions, 2 antenna
*Eggs pinsized, too small to see by eye
*Chewing mouthparts

Observations

*Beetles eat pupa
*Burrow underneath each other and oatmeal
*often mating
*Fatter, slower mealworms will pupate soon
*have trouble getting off back when fallen
*pupa have curled tail
*pupa squirm when distrubed
*active in last 3 stages
*beetles crawl around and climb
*eggs laid in clumps under oatmeal
*feel with antenna, feel edges
*mealworms enjoy moist paper towels for water, food and protection

Based on what you know about your insect and what you have observed in your cultures, what assumptions can you make about your insect?

*Because they have short legs we think it will be easier to get up from their backs if something is near them so they can grab on to it.
*Their elytra wings will make it harder to get up without assistance because they will rock side to side.

Appendix G. Sample *Initial Ideas* page from the bess bug group's *Progress Portfolio.*

Page: Initial Ideas Page 2 04/29/01, 7:5

Inquiry Project

Culture: Bess Bugs

Group Members: Sandy, Melinda, Jerri

Prior Knowledge

* They are insects.
* They eat wood (oak).
* They live in decaying logs.
* They are social insects.
* They have cursorial legs.
* They have chewing mouthparts.
* They have two antennae.
* They have a horn.

Observations

* They are good climbers.
* They hiss.
* They are active in the dark.
* They allow other Bess Bugs to crawl on them.
* They stay on, near, in, and under the logs.

Based on what you know about your insect and what you have observed in your cultures, what assumptions can you make about your insect?

-We assume that the bugs clump because they are social.
-We assume that the bugs will clump no matter the circumstance.
-We assume that the bugs clump under their environment, the wood logs, due to their preference of dark, moist, areas.

Page Type: Initial Ideas

Appendix H. Sample *Initial Ideas* page from the Isopod group's *Progress Portfolio.*

Page: Initial Ideas Page 2

Inquiry Project

Culture: Roly-polies
Group Members: Susan and Kelly

Prior Knowledge

Roly-polies are:
Isopods, family crustacea
not insects
Like lots of moisture
Have seven pairs of legs
have antannae present
Armored exoskeleton
Oval shaped
Brown or Gray
Well developed eyes
One body region
Chewing mouthparts
Small
Sowbugs have tail-like appendages
roly-polies do not
Roly-polies roll into little balls

Observations

Young are small
Young are white
Like to hide
Like the dark
Good crawlers
Cling to underside of branch
Do not bite
Normal excretion
Prefer Natural elements
Bury themselves in the dirt
Live on land
Bottom of body looks hollow
More active at night
may eat own feces
Young seem independant of adults
Mating seems traditional for bugs
Affected by movement
Antennae as feelers?
Sowbugs have tail-like appendages
Armored exoskeleton
Eat leaves

Based on what you know about your insect and what you have observed in your cultures, what assumptions can you make about your insect?

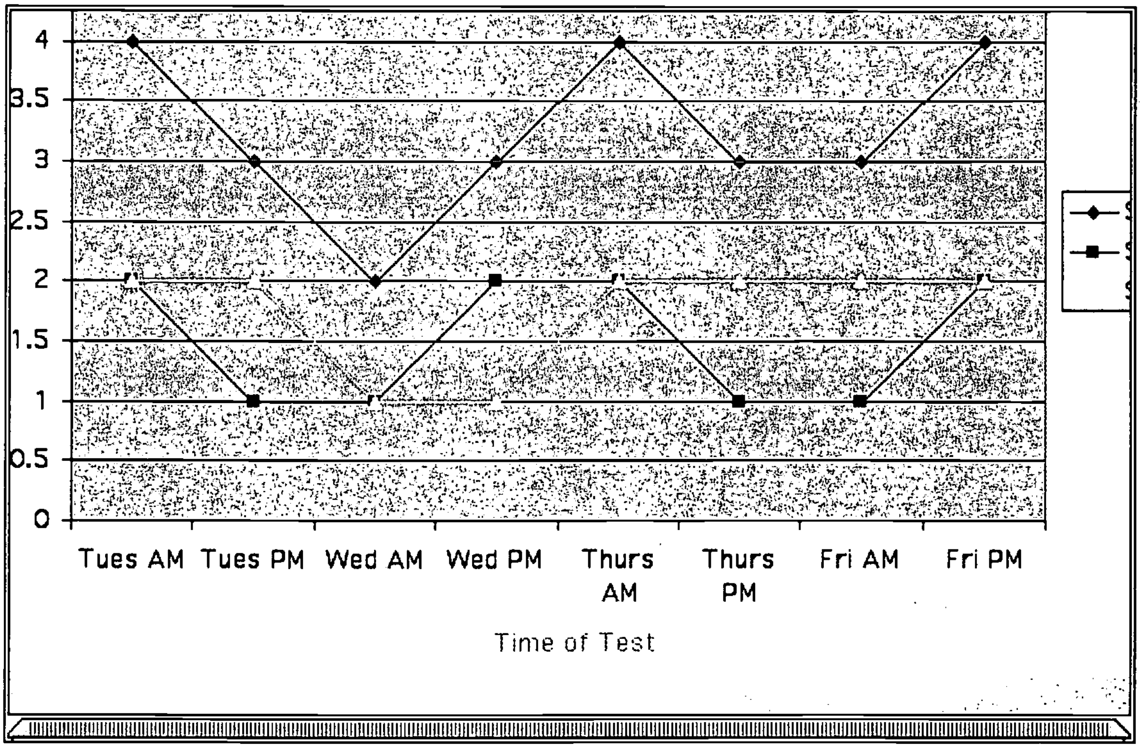
They like wet enviroments. They like naturally occuring material to live in.

Page Type: Initial Ideas

Appendix I. Sample *Data* page from the bess bug group's *Progress Portfolio.*

Page : Data Page 2 04/29/01 7:03:52

Data



What patterns are visible in this data?

This data demonstrates that the clumping continues even after the bugs were painted. At each observation, painted bugs were in the clump.

Page Type: Data

501

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