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SUNY BROCKPORT

Developing Epistemological Values in Students using Microsoft Excel® as a Software-Based Support Tool

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A Literature Review

David Peck
11/5/2012

Abstract

This thesis project addresses student epistemological values through technology and independent laboratories. The literature provides evidence that students show greater learning when they are prompted to reflect and develop these epistemological values (Davis, 2003 Demetriadis et al., 2011; Edelson & Kyza, 2005; Reiser & Sandoval, 2004). Furthermore, in conjunctions with research that supports prompting, other research advocates for the development and use of more modern technologies (Edelson & Kyza, 2005; Keengwe et al., 2008; Kuhn, 2001; Maddux, 1998). As such, my culmination project consists of two virtual "lab notebooks." These notebooks are made using Microsoft Excel® and consist of several quasi-intelligent macros that not only provide instant feedback, but also help guide students through the experimental process in a way akin to inquiry. While a completed series of these notebooks would show more scaffolding as the year progressed, the two I have created represent a student's first and last experience with these notebooks.

Key words

Epistemological values; inquiry; laboratory; scaffolding; Microsoft Excel®; technology; prompting; feedback.

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Chapter 1: Introduction

Introduction

The status of public education in New York is troubling. Our students are currently evaluated using methods that value content knowledge over higher-order thinking skills. However, we live in an age where the need to develop critical thinking, reflection, and problem solving skills far outweigh the need to memorize isolated factoids. As echoed by the new State Standards, the development of these inquiry skills should be emphasized much more than rote memorization (National Governors Association Center for Best Practices, & Council of Chief State School Officers, 2010). As a result, the roles of teachers and students are now in flux. Schools now advocate for student-centered learning and a focus on inquiry as a means for instruction (Edelson & Kyza, 2005). However, students struggle to find success through these methods because they lack epistemological values (Kuhn, 2001). While they may know of the process skills involved in engaging in inquiry, students do not have the disposition to employ them. Thus, inquiry activities are often unfruitful. One venue that is abundantly explored in the literature is the use of free open source software (FOSS) to help scaffold and nurture epistemological values (Campbell, 2009; Carey, Evans, Honda, Jay, & Unger, 1989; Collins, & Ferguson, 1993; Davis, 2003; Demetriadis, Papadopoulos, Stamelos, & Tsoukalas, 2011; Edelson & Kyza, 2005; Reiser & Sandoval, 2004). By employing software tools that help to coach how students approach a problem, construct an experiment, and assemble data, teachers can support students without directly instructing them through the inquiry process (Keengwe, Onchwari, & Wachira, 2008). These supports connect the acquisition of supporting evidence to current scientific theories and contribute to the development of students' personal epistemological values (Reiser & Sandoval, 2004).

Unfortunately, software-based support tools, while abundantly researched, are still scarce in schools today. There is a disconnect between the need for software, the funding for software (Becker & Anderson, 2001), and the type of software readily accessible to schools (Edelson & Kyza, 2005; Reiser & Sandoval, 2004). This paper will explore these current issues through the lens of developing epistemological values and offer a compromise intended to bridge the gap among the call for inquiry, the need to develop epistemological values, and the implementation of accessible software support tools.

The Need for Epistemological Values in the Current Push for Inquiry

The new State Standards in Science are another wave of impetus towards the goal of incorporating more inquiry-based science in the classroom (National Governors Association Center for Best Practices, & Council of Chief State School Officers, 2010). Efforts in the past have shared this same goal; that is, providing students with the opportunity to construct an understanding of the nature of science through more authentic means (Edelson & Kyza, 2005; NRC 1996; Reiser & Sandoval, 2004; Rutherford & Ahlgren, 1990). The focus from merely handing down factoids from teacher to student in a rote manner has shifted to one of using "process skills" (Carey et al., 1989) to back scientific claims with evidence (Edelson & Kyza, 2005; Rutherford & Ahlgren, 1990). Acknowledging the need for student learning to transcend rote memorization and instead be anchored in inquiry is important, but it is also critical that students are learning more than just the definitions of these process skills. Campbell (2009) stated that merely teaching students what the process skills of inquiry are (i.e. observation, measurement, experimental design, data analysis, etc…) is only partially involving them in the nature of science. After all, children will, to a lesser extent, learn many of these skills on their own early in life (Collins & Ferguson, 1993). Lederman, Wade, and Bell (1998), in their research, echoed the need for a more metacognitive understanding of process skills in order for students to realize gains in their understanding of the nature of science. Indeed, as Pintrich and de Groot (1990) pointed out prior to the new State Standards (2010), Campbell (2009), and Lederman et al. (1998), students must have more than just the skills, but also a willingness to employ them, if learning is to occur.

The Need for Teacher Support of Epistemological Values in the Classroom

Developing an intrinsic willingness in students to engage in metacognitive processes is a difficult task at best. At least three major changes need to occur in a teacher's pedagogy to nurture this developing. First, having expert knowledge in the field of the chosen inquiry will better prepare teachers to effectively guide students through the process (Reiser, & Sandoval, 2004; Schauble et al., 1991; Tabak et al., 1996). By having adequate content knowledge of the discipline in which his students are exploring, a teacher is more capable of emphasizing the specific aim of the activity and direct students to produce products that better support the "why" of a phenomenon rather than the "what" (Carey et al., 1989).

Second, teachers must make the shift from traditional methods of teaching, especially those based on rote memorization, to a more constructivist perspective. Many teachers teach in the manner that they were taught (Mehlinger & Powers, 2002), and making such a shift could potentially mean learning and developing an entirely new pedagogy based on the notion that students learn more effectively when they take ownership of their learning (Henson, 2004; Keengwe et al., 2008). Additionally, the extent of this shift in perspective must permeate the routine of the classroom. Reiser and Sandoval (2004) argue that effective inquiry can only be accomplished when both the teacher and their students readjust the nature of their work as well as the latent, fundamental view of their work. This means, as previously alluded to by both Pintrich and de Groot (1990) and Lederman et al. (1998), that certain epistemological values, such as a willingness to employ process skills and an ardor to pursue evidence, need to be cultivated within students who engage in inquiry if those students are to retain the gains from their participation (Carey et al., 1989). Students not only need to be taught what these epistemological values are, but also be provided the time to develop them (Collins, & Ferguson, 1993; Kuhn, 2001). This can most effectively be accomplished, according to Carey et al. (1989), if both the process of inquiry and a constructivist epistemology lace the science curricula.

Third, with ample content knowledge and an established atmosphere conducive to epistemological development, the last undertaking that a teacher must take to shape the development of the nature of science in his students is to incorporate the proper supports. While supports can range from simple pneumonic devices to expensive technology and new pedagogical techniques, the focus of this paper will be on computer-based software. Not only does such technology allow students to be more productive, but it also offers an array of new venues to address the development of students' views of the nature of science (Keengwe et al., 2008).

Chapter 2: Review of the Literature

Connecting Epistemological Values to Student Learning

In order to see the benefits of software-based inquiry support tools, it is important to understand both how students develop epistemological values and how these values direct their learning (Reiser & Sandoval, 2004). Carey et al. (1989) add that this is also a key to engaging students. Epistemological values are the dispositions that a student has towards engaging in the process of inquiry. There is also a distinct, albeit latent, difference between a "disposition" and a "competence" of engaging in the process of inquiry (Kuhn, D., 2001). As Kuhn puts it, being able to go through the motions of inquiry is not sufficient to realize and maintain the gains of the process. A "competence" of inquiry process skills is more akin to memory recall, the first tier of Bloom's Taxonomy, whereas the cultivation of a disposition to apply process skills relates more to his higher tiers. Where the process skills of inquiry might simply be to question, observe, experiment, analyze, and conclude on data, epistemological values are the questions that drive a student to apply these skills in the first place. According to Kuhn, these are questions such as "Is there something to find out?" "Is analysis worthwhile?" "Is arguing worthwhile?" "Are unexamined beliefs worth having?" and above all, "What is knowing?" Thus, the goal of inquiry – and indeed learning in general – is to nurture these epistemological values, in turn allowing students to more actively engage, more effectively learn, and more deeply understand the nature of science and what counts as scientific knowledge (Carey et al., 1989; Reiser & Sandoval, 2004).

Student Development of Epistemological Values

However, nurturing epistemological values is more easily said than done. Students often fail to adequately develop epistemological values and thus struggle with the connection between scientific claims and the need for evidence (Carey et al., 1989; Edelson & Kyza, 2005; Krajcik et al., 1998; Kuhn, 2001; Kuhn, Amsel, & O'Loughlin, 1988; Reiser & Sandoval, 2004; Zimmerman, 2000). In Kuhn's (2001) study, 4- to 6-year -olds were given a series of pictures that inferred a simple story, such as a picture of two people racing followed by a picture of one holding a trophy. These children where then asked to describe what happened and how they justified their claims. Instead of providing evidence for their claims, the majority of the items were instead supported by a mixture of explanation and inference (for example, as opposed to citing the trophy as evidence to the victory, some children claimed that the color of the runner's shoes allowed him to run faster). This perhaps does not demonstrate young children's failure to develop epistemological values, but instead suggests that young children do not yet have the logic of confirmation available to them (Carey et al., 1989; Inhelder & Piaget, 1958).

Where this lack of drive for evidence becomes disconcerting is when these children enter the middle school grades. In these grades, supporting claims with evidence becomes an important focus, but to the dismay of many students, the process skills and epistemological values that drive such a task are underdeveloped or nonexistent (Carey et al., 1989; Edelson & Kyza, 2005). In a study done by Kuhn et al. (1988), children ranging from eight to 14 years were given the task to evaluate whether the features of tennis balls, such as size and texture, would affect a player's serve. Not only were many of the subjects' personal views submitted as possible hypotheses, many subjects struggled with the idea of generating evidence. Even when given a set of data and asked to evaluate their hypotheses based on the given data set, subjects had difficulty. This faulty reasoning, according to Kuhn et al., suggested that even children older than those of Kuhn's (2001) study fail to recognize the distinction between the natures of theory and evidence. Even more disheartening is that this study was also given to adults with similar results.

Such evidence suggests – especially because adults continue to struggle with the notions of theory and evidence – that the development of epistemological views is lacking in students' education (Carey et al., 1989; Edelson & Kyza, 2005; Kuhn, 2001; Kuhn et al., 1988; Reiser & Sandoval, 2004). According to Duschl (1990), this is because most of what is taught in science classrooms today is "final form" science, where theories and facts are presented to students as arbitrarily true and disjointed from the process by which they arose. And it is irrelevant whether this stemmed from tradition, laziness, or the pressure of high-stakes exams, because in the end "final form" science does not accurately portray how information is created (Reiser & Sandoval, 2004). Furthermore, such instruction favors memorization over the application of process skills, which, at best, encourages lower level thinking skills rather than higher order ones. Epistemic knowledge, then, is neither explicitly taught nor effectively modeled in public education (Collins et al., (1989). Thus, very few students ever have the chance to construct appropriate epistemological values (Driver et al., 1996). However, contrary to the claims of Kuhn et al. (1988), middle school students are capable of shaping appropriate scientific dispositions if proper supports and scaffolding are embedded throughout the curriculum (Carey et al., 1989; Collins & Ferguson, 1993; Edelson & Kyza, 2005; Reiser & Sandoval, 2004; Sandoval, 2003).

Fostering Epistemological Values through Prompting and Reflection

Epistemological values are shaped through metacognitive engagement. This metacognitive engagement stems mostly from students being prompted to reflect on the activity or their work. Demetriadis et al. (2011) argued that prompting promotes cognitive engagement in both well- and ill-structured domains by affording students the opportunity to deeper process the materials at hand. Furthermore, prompting scaffolds an activity to help keep students from engaging in tasks superficially (Pressley et al., 1992). In the study by Demetriadis et al. (2011), two groups of students were asked to complete a software-based learning module on a common topic. Though both groups completed the same module, one group of students completed a version of the program that included mandatory reflective prompts. While completing the prompts was required to progress through the module, they were not graded or assessed in any way. Based on significant differences between pre- and post-test scores, the researchers found that the group required to complete the reflective prompts outperformed the non-prompted group. This, the researchers concluded, suggested that performance (a result of developed or underdeveloped cognitive processes) is beneficially affected by prompting. According to Demetriadis et al., the prompted students spent more time engaging in productive cognitive activity, which in turn helped mold and engage epistemological values. In doing so, students were more inclined to search for identifying clues in the context, evaluate these clues against those found in previous contexts, and artfully express their conclusions. Similar work from Ge and Land (2003) cited that students who received prompting in different problem-solving processes, ranging from problem representation to justification and evaluation, performed significantly better than those without prompting. Furthermore, the work of Davis (2003) also echoed the connection between prompting and the development of epistemological values by explaining that prompts, specifically those designed to have students self-monitor, engage students in the process of knowledge integration. That is, when students are given the opportunities to appropriately extend their current range of ideas, they can make distinctions and connections between these ideas, and identify knowledge gaps or weaknesses (Linn, 1995). Additionally, prompts that explicitly call for the students' metacognitive assessment encourage student reflection regarding their problem-solving process (Coleman, 1998; Collins, Brown, & Holum, 1991; Gunstone, Gray, & Searle, 1992; King & Rosenshine, 1993; Schoenfeld, 1987; White & Frederiksen, 1995, 1998). Such reflection can be extended to focus on the process of inquiry, and seamlessly shift from a student's problem-solving process to his inquiry methods, experimental design, and conclusions.

Limitations of Prompting and Reflection

Epistemological development is most effective only when both the focus of reflection and the prompts that elicit these processes are carefully written and varied. While the research suggests that embedding prompts throughout the activities of the curriculum will indeed promote student learning, reflection, and development of epistemological values, it is important to note the dangers of over-prompting. Prompting students to engage in metacognitive processes too frequently can result in the opposite effect (Davis, 2003). Davis argued that students are "cognitive economists," and when too mentally taxed, will avoid investing effort (or in this case, engaging in cognitive processes) within the task they have deemed too tedious. Specifically, though, it is the balance between the frequency and variation of prompts that classifies an activity as one with a problem of over-prompting. In fact, the realm of varied prompting and students' learning processes is well researched (Azevedo et al., 2004; Bannert, 2006; Clark & Mayer, 2003; Davis & Linn, 2000; Hmelo & Day, 1999; Lin & Lehman, 1999; van den Boom, Paas, van Merrienboer, & van Got, 2004). Ge (2001) stated that supporting students with prompts may promote both the students' competence and disposition to problem solve and to engage in reflective thinking. Question prompts, or sets of guiding questions, offer cognitive and metacognitive support (Ge, 2001) while elaboration prompts that persistently ask students "why" can result in more effective factual and inferential learning (Woloshyn et al., 1990). Thus, while it is clear that consistent prompting before, during, and after activities bolsters understanding and expedites the maturation of epistemological beliefs (Linn & Songer, 1991; White & Frederiksen, 1998), it is important that prompts are carefully and tactfully incorporated (Davis, 2003). Over-prompting does not always occur when activities are heavily scaffolded with prompts, but is instead more often the result of poorly devised prompts.

Supporting Epistemological Values through Software Support Tools

Software-assisted inquiry has been shown to effectively incorporate metacognitive and self-monitoring prompts that promote both student reflection and a deeper understanding of the material (Demetriadis et al., 2011; Edelson & Kyza, 2005; Reiser & Sandoval, 2004). In the study done by Lin and Lehman (1999), students saw gains in the understanding of their own learning processes through a computer-based biology simulation that had integrated prompts for reflection. In addition, van den Boom et al. (2004) suggested that prompting students for reflection in the context of hypermedia and web-based learning environments provided similar benefits. These claims are further supported by the recent research of Azevedo et al. (2004) and Bannert (2006). Since several studies exist that provide evidence connecting the use of hypermedia to the beneficial development of epistemological beliefs, it is clear that similar expectations must be applied to software-based inquiry tools. For any software-based inquiry support to most genuinely and effectively help shape students' epistemological values, it must contain an aspect that provides exploration opportunities of hypermedia. After all, it is also the nature of science to actively push ourselves to explore past the avenues with which we are comfortable or familiar (Carey et al., 1989).

Edelson and Kyza (2005) presented a study that supported the use of a software-based inquiry tool as an effective scaffold for students' coordination between the spheres of theory and evidence. This particular support was a Linux-based, open source software program called Progress Portfolio. During the course of an evidence-driven investigation of evolutionary biology, the students in Edelson and Kyza's study showed significant differentiation between hypothesis and evidence. This contradicted the disheartening claims previously made by Kuhn et al. (1988) because it suggested that middle school students are indeed capable of constructing epistemological values with the intervention of software support tools (Edelson & Kyza, 2005; Kuhn, 2001). One possible explanation could be the difference in the dates when these studies took place. There was little – if any – implementation of technology in the classroom during the late 1980s. This is a stark contrast to the classrooms we see today, and Edelson and Kyza (2005) argued that the presence of software scaffolding helped to make the need for developing evidence-based explanations explicit and transparent to students. This notion is also echoed by Reiser and Sandoval (2004), who cited that these tools support thinking in epistemologically valued ways by providing an element of structure to developing students' articulation. Such software also served as a guiding prompter while students shaped appropriate scientific dispositions. Indeed, by employing such tools throughout the curriculum, teachers can engage students' thinking in a way geared more toward evidence (Carey et al., 1989; Lajoie, 1993; Reiser, 2002; Reiser & Sandoval, 2004) and the development of epistemological values (Keengwe et al., 2008; Kuhn, 2001). Furthermore, such a shift from "final form" science to more authentic discovery is not only aligned with the new State Science Standards, but also responds to the call for teachers to assume the role of model and guide rather than lecturer (National Governors Association Center for Best Practices, & Council of Chief State School Officers, 2010; Sharp, 2006).

Obstacles of Implementing Software Support Tools

Much of the previous literature cited the use of programs that were created as free open source software (FOSS), especially in the fields of educational technology, inquiry, and the cultivation of students' views of the nature of science. Programs such as Inquiry Island®, MindRaider®, Progress Portfolio®, and Sugar® all have literature that backed their effectiveness as support tools in guiding students to appropriately construct epistemological values regarding the nature of science and the need for evidence (Edelson & Kyza, 2005; Reiser & Sandoval, 2004). It is curious, then, that the use of these programs is not more widespread throughout the education system. However, research also cites that the reason many of these emerging technologies fail to become more prevalent stems from the plethora of obstacles facing the incorporation of instructional technology in the classroom (Becker & Anderson, 2001; Keengwe et al., 2008; Maddux, 1998; Rogers, 1999). The trials of effectively introducing technology as a support to learning have existed since the 1980s (Rogers, 1999), and while huge steps have been made in physically getting the technology into the hands of students (Becker & Anderson, 2001), many still experience a crippling lack of technological resources to fully implement them in the curriculum (Becker & Anderson, 2001; Hug & Zucker, 2008; Maddux, 1998). According to Becker and Anderson (2001), the capita per student for hardware has been over 70% of all technology-related spending since before the turn of the millennium. However, though the permeation of technology has not fully reached every school, and while many might argue that our schools will never be adequately equipped, a more salient obstacle is the lack of funding for software in schools. One of the greatest benefits of FOSS, as its name implies, is that it is free. Unfortunately, though, the vast majority of FOSS is based on a Linux operating system. Thus, even though the software is free, it is still unavailable to most schools because the more ubiquitous platforms are Windows- or Mac-based. As a result, schools are instead left with limited software that is not only rare for the platforms on which their computers run, but also expensive to subscribe to. And where many schools are indeed seeing more hardware in each classroom, less than seven percent of the capita per student in the category of technology has been spent on software. Such little spending suggests that not only the variety, but also the quality of software that students are exposed to is limited at best. Furthermore, it illustrates the lack of balance between acquiring and utilizing technology (Borrell, 1992; Piller, 1992; Rogers, 1999). Computers are rarely more than supplementary references for teachers in lesson planning or for students in word processing Cuban (2001). Little has been done to adequately train teachers and students so that they may see learning gains from new technology (Keengwe et al., 2008; Maddux, 1998).

While access and exposure is indeed a large aspect of why technology has yet to significantly affect the learning process for the better (Anderson, 1993; Becker, 1986; Ginserb & McCormick, 1998; Hooper & Reiber, 1995; Reiber & Welliver, 1989; Schieman & Fiordo, 1990; Spotts & Bowman, 1993), similarly profound obstacles are sociocultural factors (Bereiter, 1994) and the attitudes of teachers (Marcinkiewicz & Grabowski, 1992). In a survey done by Rogers (1999), where 10,000 teachers were asked about their dispositions towards technology and their beliefs as to why it is not more intimately apparent in the education system, many claimed that there was such a lack of time, funding, and training in emerging technologies that many resisted the notion of more fully incorporating technology into their pedagogy. These claims echoed those of an earlier study by Fabry and Higgs (1997) and are again repeated in more recent works by Beggs (2000). The incentive for this paper is to highlight that, while economic factors certainly play a part in keeping technology from being effectively incorporated into teachers' curricula, another important factor is the general attitude from teachers that technology burdens rather than alleviates many of the stresses in the classroom. While politicians and benevolent institutions donate millions of dollars so that schools can lease emerging software tools, funding is often transient and not comprehensive (Ficklen & Muscara, 2001). That is, schools are often blessed with new software, but either the lack of consistent funding for lease subscriptions or a failure to train the faculty in the use of it ultimately ends in ineffective integration and the emergent technology being subsequently dropped (Keengwe et al., 2008). One can see how such a cycle of investment and disappointment can disenchant teachers. This cycle, though, has facets that can be altered to provide many teachers with an escape towards a more positive outlook. The most critical of these facets lie in the software itself. While the multitude of software-based support tools mentioned earlier in this paper (i.e. Inquiry Island®, Progress Portfolio®, etc…) are indeed powerful and have been shown to cultivate epistemological values within students (Campbell, 2009; Edelson & Kyza, 2005; Demetriadis et al., 2011; Reiser & Sandoval, 2004), they are all FOSS and Linux-based. The majority of teachers, if they have even heard of Linux at all, are not familiar with the operating system (Keengwe et al., 2008). Furthermore, the operating systems in schools are predominately Windows- or Mac-based. Thus, even if teachers were able to acquire such software as Inquiry Island® or Progress Portfolio®, they would need both the technical expertise as well as the administrative permission to be able to dual-boot each and every computer they plan to run the program on each day. In light of these challenges, it is understandable that many teachers have developed an apprehension for emerging technology (Keengwe et al., 2008; Maddux, 1998; Rogers, 1999).

Using Excel® as a Software Support Tool to Develop Epistemological Values

The benefits of software-based support tools, especially in the inquiry process, have already been cited within this paper (Campbell, 2009; Carey et al., 1989; Collins & Ferguson, 1993; Davis, 2003; Demetriadis et al., 2011; Edelson & Kyza, 2005; Reiser & Sandoval, 2004). Given the obstacles in acquiring and utilizing FOSS, the task for teachers now is to find a way to translate the mechanisms in FOSS that expedite the development of mature epistemological values to a more familiar platform. I was unable to find any previous literature on using Excel as an inquiry support tool. On the other hand, as cited throughout the extent of this paper, the importance of using such a tool is significant. Thus, the disparity between the need for software-based inquiry support and its scarcity in the field is jarring. It is surprising that Microsoft Excel® has not been seriously considered as a useful support tool past making graphs of lab data in science classes. Perhaps this is because many teachers are not familiar with the extent of the program's capabilities (Keengwe et al., 2008), or perhaps this lapse in utilization stems from apprehensions of technology being more trouble than it is worth (Hug & Zucker, 2008; Keengwe et al., 2008; Maddux, 1998; Rogers, 1999). In either case, the task of eliciting the same benefits from using Excel® as from using FOSS is much less insurmountable than the array of other obstacles (i.e. funding and sociocultural factors) surrounding the implementation of technology in the classroom (Becker & Anderson, 2001; Bereiter, 1994; Maddux, 1998; Marcinkiewicz &

Grabowski, 1992). First, funding would not be much of an issue because the Microsoft Office Suite® and its Macintosh® counterpart are mostly ubiquitous in schools for their word processing programs. Excel® is included as one of the programs within the suite. This means that every computer in the school that has Microsoft Word® installed will also be capable of running Microsoft Excel®. Thus, teachers would not need to dual-boot the computers they intend to run an inquiry support program on or even worry about whether or not the computers have the program installed. Second, the program contains many of the same elements that the FOSS in previous research utilized to see gains in student reflection and development of epistemological beliefs. An Excel® file can be outfitted with complex macros that simulate an artificial intelligence, akin the guides found in Inquiry Island®, and offer similar prompts to students that evoke reflection or critical thinking. For example, once a student fills out a designated cell for a hypothesis, a separate macro can check to see if keywords have been mentioned, another can check to see how long the hypothesis is, and a third could display a pre-programmed response based in the conditions of the first two. This feedback would be instantaneous and allow students to self-monitor themselves more effectively and efficiently than if they needed to wait for the one teacher in the classroom to check their work. Third, Excel® is capable of incorporating outside programs through the use of hyperlinks and object embedding. This puts Excel® almost in the role of a virtual learning environment, as students have the opportunity to explore not only the content created within the program by the teacher, but also any content that is available on the internet or through a third party program. This dynamic capacity allows both teachers and schools to also avoid the financial and logistical obstacles that often accompany subscription-based software programs. Fourth, the Excel® program is customizable and can cater to the whims of both the teacher and students. As the class progresses through the year, the teacher would be capable of changing the topics to be explored, the variety of resources used, and the caliber with which the activity is scaffolded. And because an Excel® spreadsheet is endlessly expandable, neither the teacher nor the students would be fettered by a rigid canvas. Teachers could create colorful, interactive, and intuitive digital notebooks to coincide with an inquiry lab, while students would be capable of presenting their data and conclusions within the program in an infinitely imaginative way. The versatility of Excel® is therefore limited only by the capabilities of the user, and while teachers will still struggle at the onset – as is the norm for any preliminary exposure – even a basic level of familiarity could adequately help shape the development of epistemological values.

Chapter 3: Applications

Excel®-Based Scientific Notebooks

To illustrate the applications of this research, I have created two example Excel®-based scientific notebooks. Not only can these be considered examples of how to utilize the vast array of tools that are available in Excel®, but they are also the product of one teacher who had only a basic level of familiarity with the program. While it may appear that I had more knowledge and skill with Excel® than someone who only uses it to plot graphs, the only difference me and the latter was that when my imagination extended beyond my skill, I consulted the program's built-in help function. A full year's worth of files does not exist. Rather, these two notebooks are meant to be the student's first and final experiences, respectively, with this kind of activity. The first notebook is heavily scaffolded to allow the student to learn the content material within it – which in this case is the scientific method – while learning how to use the program at the same time. Again, the level of scaffolding throughout the year should reflect the student's capacity to engage epistemological values rather than dependent on the programming of the Excel® files to do the work. Thus, the second notebook, while still containing similar qualities and venues for outside resources as the first, if far less structured and works more as a canvas with which the student can create their own research project. To view these two notebooks, save their files to a computer from the supplemental files section of the Digital Commons. In order for them to work, the computer they are saved to must already have Microsoft Excel® installed.

Chapter 4: Conclusion

Conclusion

Student learning is always a goal in education, but we cannot forget that contingent to successful student learning is the proper development of epistemological beliefs. The dispositions of students to engage in the process of inquiry direct how and to what caliber students achieve success in an activity (Carey et al., 1989; Kuhn, 2001). Through effective prompting and reflection, students can be periodically reminded to assess their process of thought and expedite the maturation of acceptable epistemological values. Thus, it is paramount that teachers utilize methods that prompt students to engage in self reflection. One of the effective methods discussed in this paper was the use of software-based support tools as both a guide through the process of epistemological development and a consistent prompter of student reflection (Edelson & Kyza, 2005; Reiser & Sandoval, 2004). However, this tool has yet to be successfully integrated into the classroom. Among the issues surrounding school budgets and the economy (Becker & Anderson, 2001), there are those of teacher perspectives and accessibility. Many teachers fail to utilize technology in general because it either differs from their own beliefs about teaching or they simply lack the technical prowess (Keengwe et al., 2008; Maddux, 1998). As mentioned before, both of these barriers have merit. While the research on the benefits of using software-based support tools is abundant and well-explored, the type of software used in the literature is not only beyond the teachers' realm of familiarity, but also the operating systems of the computers in the majority of schools. In reality, the evidence that supports the use of software tools really has no meaning since the software tools are not accessible to the classroom teacher. This is the disconnect that might be ameliorated by the Microsoft Excel® program. Because Windows- and Mac-based operating systems, along with Microsoft Excel®, are far more ubiquitous than Linux-based operating systems and their transient FOSS, there is potential of utilizing the Excel® program to address the needs of epistemological support within the classroom. Excel® is a hidden gem that teachers already have access to. Not only is it customizable to a near limitless degree, but it is capable of supporting a student's development of epistemological values through the use of guiding, quasi-artificial intelligence macros, embedded hyperlinks, and prompts that promote student reflection. It is therefore also a salient candidate for supporting inquiry. Not only can it be shaped to fit the teacher's needs, but it can be a student-centered tool that guides them through the process of inquiry, fosters epistemological values, and contributes to a stronger foundation behind their learning.

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Appendix

The following is an example of some of the macro language found in the programming of the Microsoft Excel® notebooks. These macros spawn feedback boxes, evaluate text in a cell, and assist in the formatting of student writing, respectively:

This is a macro consisting of several yes/no questions aimed to highlight a student's inherent curiosity and propensity to seek proof.

```
Sub ScientistScenario()
' Keyboard Shortcut: Ctrl+a
Dim Msg, Style, Title, MyString1, MyString2, Style1, Style2, Title1,
Title2, FinalMsg1, FinalStyle1, FinalTitle1
```

```
Msg = "One of the kids in the class claims that she can run faster
than everyone else in the room. In fact, she claims she could outrun
anyone even if she were wearing a backpack filled with 80lbs of books!
You believe her, right?"
Style = vbYesNo + vbQuestion + vbDefaultButton2
Title = "You are a scientist, believe it or not!"
MyString1 = "Would you offer to race her?"
MyString2 = "Would you be curious to see if she could beat someone
even while wearing that backpack?"
Style1 = vbYesNo + vbQuestion + vbDefaultButton1
'Style2 = vbYesNo + vbInformation + vbDefaultButton1
Title1 = "Being a believer, eh?"
Title2 = "You want proof, don't you?"
FinalMsg1 = "That is being a scientist! You are searching for proof of
something!"
FinalStyle1 = vbExclamation
FinalTitle1 = "Good job my young apprentice!"


Response = MsgBox(Msg, Style, Title)
If Response = vbYes Then
GoTo Line1
ElseIf Response = vbNo Then
GoTo Line2
End If

Line1:
Response = MsgBox(MyString1, Style1, Title1)
If Response = vbYes Then
GoTo Line3
ElseIf Response = vbNo Then
GoTo Line2
End If

Line2:
Response = MsgBox(MyString2, Style1, Title2)
If Response = vbNo Then
GoTo Line1
ElseIf Response = vbYes Then
GoTo Line3
End If

Line3:
```

```
Response = MsgBox(FinalMsg1, FinalStyle1, FinalTitle1)


End Sub
```

This is the first feedback macro that the student is exposed to. It is a simple evaluation of a text box that checks to make sure the student wrote the correct definition of the word 'research.' There are variable responses depending on the level of the student's completeness.

```
Sub FirstFeedbackCheck()
'
' FirstFeedbackCheck Macro
'
Dim Msg1, Style1, Title1, Msg2, Style2, Msg3, Msg4

Msg1 = "Great job! You've wrote down everything I was looking for!"
Style1 = vbExclamation
Title1 = "Your First Feedback Check!"
Msg2 = "I don't think you copied down the correct definition. Also,
you didn't punctuate!"
Style2 = vbCritical
Msg3 = "Are you sure you wrote down the whole definition? Go back and
make sure you didn't leave any important words out!"
Msg4 = "You've got everything, but you didn't punctuate!"

Application.ScreenUpdating = False

Questioning:

Worksheets("Questioning").Range("O108").Copy _
    Destination:=Worksheets("Questioning").Range("A108")

With Worksheets("Questioning").Range("A108")
    Set V = .Find("Diligent", LookIn:=xlValues)
    Set C = .Find("Investigation", LookIn:=xlValues)
    Set B = .Find("Inquiry", LookIn:=xlValues)
    Set A = .Find("Systematic", LookIn:=xlValues)
    Set X = .Find(".", LookIn:=xlValues)

    If A Is Nothing And B Is Nothing And C Is Nothing And V Is Nothing
And X Is Nothing Then
```

```
            Response = MsgBox(Msg2, Style2, Title1)
    ElseIf A Is Nothing Then
            Response = MsgBox(Msg3, Style2, Title1)
    ElseIf B Is Nothing Then
            Response = MsgBox(Msg3, Style2, Title1)
    ElseIf C Is Nothing Then
            Response = MsgBox(Msg3, Style2, Title1)
    ElseIf V Is Nothing Then
            Response = MsgBox(Msg3, Style2, Title1)
    ElseIf Not A Is Nothing And Not B Is Nothing And Not C Is Nothing
And Not V Is Nothing And X Is Nothing Then
            Response = MsgBox(Msg4, Style2, Title1)
    Else
            Response = MsgBox(Msg1, Style1, Title1)
    End If
End With

Exit Sub
'
End Sub
```

This is another feedback macro that checks to make sure the student has fully filled out their hypothesis.

```
Sub EvalHypothesis()
'Hypothesizing Notebook1

'
Dim Msg1, Style1, Title1, Title2, Msg2, Style2, Msg3, Msg4, Msg5, Msg6

Msg1 = "I think we can work with that hypothesis! :)"
Style1 = vbExclamation
Title1 = "Great Job!"
Msg2 = "The first box in your hypothesis is incorrect..."
Style2 = vbCritical
Title2 = "You've got some editing to do..."
Msg3 = "You haven't decided how you are treating the liquid..."
Msg4 = "The third box in your hypothesis is incorrect..."
Msg5 = "The fourth box in your hypothesis is incorrect..."
Msg6 = "The fifth box in your hypothesis is incorrect..."

Application.ScreenUpdating = False
```

```
X = 0

Hypothesizing:

Worksheets("Hypothesizing").Range("D85").Copy _
    Destination:=Worksheets("Hypothesizing").Range("A85")

Worksheets("Hypothesizing").Range("G85").Copy _
    Destination:=Worksheets("Hypothesizing").Range("A86")

Worksheets("Hypothesizing").Range("K85").Copy _
    Destination:=Worksheets("Hypothesizing").Range("A87")

Worksheets("Hypothesizing").Range("Q85").Copy _
    Destination:=Worksheets("Hypothesizing").Range("A88")

Worksheets("Hypothesizing").Range("R85").Copy _
    Destination:=Worksheets("Hypothesizing").Range("A89")

With Worksheets("Hypothesizing").Range("A85")
    Set A = .Find("If", LookIn:=xlValues)

    If A Is Nothing Then
            Response = MsgBox(Msg2, Style2, Title2)
            Exit Sub
    ElseIf Not A Is Nothing Then
            X = X + 1
    End If
End With

With Worksheets("Hypothesizing").Range("A86")
    Set B = .Find("", LookIn:=xlValues)

    If Not B Is Nothing Then
            Response = MsgBox(Msg3, Style2, Title2)
            Exit Sub
    ElseIf B Is Nothing Then
            X = X + 1
    End If
End With

With Worksheets("Hypothesizing").Range("A87")
    Set C = .Find("then", LookIn:=xlValues)
```

```
    If C Is Nothing Then
            Response = MsgBox(Msg4, Style2, Title2)
            Exit Sub
    ElseIf Not C Is Nothing Then
            X = X + 1
    End If
End With

With Worksheets("Hypothesizing").Range("A88")
    Set D = .Find("will", LookIn:=xlValues)

    If D Is Nothing Then
            Response = MsgBox(Msg5, Style2, Title2)
            Exit Sub
    ElseIf Not D Is Nothing Then
            X = X + 1
    End If
End With

With Worksheets("Hypothesizing").Range("A89")
    Set E = .Find("increase", LookIn:=xlValues)
    Set F = .Find("decrease", LookIn:=xlValues)
    Set G = .Find("not change", LookIn:=xlValues)

    If E Is Nothing And F Is Nothing And G Is Nothing Then
            Response = MsgBox(Msg6, Style2, Title2)
            Exit Sub
    Else
            X = X + 1
    End If
End With

If X = 5 Then
Response = MsgBox(Msg1, Style1, Title1)
Exit Sub
End If
'
End Sub
```

This macro synthesizes three of the student's written concluding paragraphs into one body of writing.

```
Sub MergingParagraphs()
'
' MergingParagraphs Macro
'

'Worksheets("concluding").CheckSpelling

Worksheets("Concluding").Range("M17").Copy _
    Destination:=Worksheets("Concluding").Range("A83")
'    With Worksheets("Concluding").Range("A83")
'        '.CheckSpelling
'        .WrapText = False
'        .Font.Size = 1
'        .ShrinkToFit = True
'    End With

Worksheets("Concluding").Range("A83").Copy _
    Destination:=Worksheets("Concluding").Range("D83:T90")
'    With Worksheets("Concluding").Range("D83")
'        '.CheckSpelling
'        .WrapText = True
'        .Font.Size = 15
'    End With

'Worksheets("Concluding").Range("D83:T90").ShrinkToFit = True

Worksheets("Concluding").Range("M38").Copy _
    Destination:=Worksheets("Concluding").Range("A91")
'    With Worksheets("Concluding").Range("A91")
'        '.CheckSpelling
'        .WrapText = False
'        .Font.Size = 1
'        .ShrinkToFit = True
'    End With

Worksheets("Concluding").Range("A91").Copy _
    Destination:=Worksheets("Concluding").Range("D91:T98")
'    With Worksheets("Concluding").Range("D91")
'        '.CheckSpelling
'        .WrapText = True
```

```
'        .Font.Size = 15
'    End With

'Worksheets("Concluding").Range("D91:T98").ShrinkToFit = True

Worksheets("Concluding").Range("M59").Copy _
    Destination:=Worksheets("Concluding").Range("A99")
'    With Worksheets("Concluding").Range("A99")
'        '.CheckSpelling
'        .WrapText = False
'        .Font.Size = 1
'        .ShrinkToFit = True
'    End With

Worksheets("Concluding").Range("A99").Copy _
    Destination:=Worksheets("Concluding").Range("D99:T106")
'    With Worksheets("Concluding").Range("D99")
'        '.CheckSpelling
'        .WrapText = True
'        .Font.Size = 15
'    End With

'Worksheets("Concluding").Range("D99:T106").ShrinkToFit = True

End Sub
```

This macro transfers the student's question to a location at the bottom of the sheet as well as records the exact date and time that the student pressed the macro. This acts as a timestamp for both the student's and teacher's records.

```
Sub Timestamp1()
'
' Timestamp1 Macro
'
Dim Msg, Style, Title
Msg = "Successful!"
Style = vbOKOnly + vbExclamation
Title = "Timestamp"

    Range("D123").Select
    Selection.Copy
    Range("D124").Select
```

```
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False
    Application.CutCopyMode = False

    Range("E123").Select
    Selection.Copy
    Range("E124").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False
    Application.CutCopyMode = False

Worksheets("Questioning").Range("H121").Copy _
    Destination:=Worksheets("Questioning").Range("A121")

Response = MsgBox(Msg, Style, Title)

End Sub
```