Computational Thinking for Middle School: A Case Study of an 8th Grade Multimedia Outreach Project

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1. ABSTRACT

We describe the STEM Careers Infographic Project (SCIP), an outreach project for 8th grade students. The goal of SCIP was to get students interested in STEM by letting them research their own careers and create infographics. We utilized the CSTA's Computational Thinking definition and progression chart to help develop the curriculum; and Sandoval's conjecture mapping framework to structure and evaluate the project. This project was implemented in spring of 2015 with 153 students, 68% of which were from traditionally underserved communities. SCIP encountered theoretical and design obstacles during deployment that helped us modify the final project design. In the end, we present a multimedia, computational thinking unit that can be adopted by a non-expert at the middle school level.

Keywords

infographics; middle school; curriculum

2. BACKGROUND

Infographics have permeated our culture as a leading form of information display and communication. They can be seen everywhere from business and news to social media websites. Infographics are also unique, since they combine beautiful visualization with an impactful way to deliver direct information. It has been demonstrated that infographics can be used to advise non-expert audiences so they can make informed decisions [1]. They have also been used as an extremely effective communication tool over traditional tools such as email and reports [5].

The attraction of infographics seems to be inherent within their nature, since people are drawn to the visualizations, colors, and images they provide [6]. An infographic can transfer knowledge about a topic faster and more effectively than pure text; however, this condition is dependent on the quality and presentation of the infographic. Despite the popularity of infographics in the public realm, there has been little research addressing the potency of infographics as a learning tool. Vanichvasin conducted a study with fourth-year university students, where infographics were used a visual communication tool in a Business class [8]. Results from the study showed that infographics have the potential to enhance appeal of the course, yield a positive impact, and enhance the quality of learning.

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Krauss advocates the use of infographics in K-12 classrooms in her paper *Infographics: More Than Words Can Say* [5]. She lists five simple steps to follow when creating an infographic, and gives example projects where infographics can be used in the classroom.

In 2014, Kos and her colleagues used infographs in a middle school classroom as a replacement for writing a 5-paragraph essay [4]. She found that students responded positively to using infographs in the classroom as a learning tool. Her students liked the open-ended project she provided as well as the freedom and creativity the infographics offered.

Aside from the Krauss and Kos articles, we have found very little research regarding using infographics in K-12 level as a learning tool. We aim to further the research listed here by showing that infographics can be an appropriate and advantageous tool improving communication and computational thinking skills at the middle school level.

3. INTRODUCTION

In the spring of 2015, the authors developed an infographic project, "STEM Careers Infographic Project" (SCIP), by using Krauss' infographic principles and adapting Kos' curriculum structure. The authors then collaborated with an 8th grade teacher, Ms. Swanson, from Montaña Vista Middle School (MVMS)[1] to finalize the curriculum and create a timeline for the project. SCIP was a career project that required students to research a career, find a STEM connection to that career, report their findings in an infographic, and present their infographic to the class.

3.1 School Choice and Demographics

MVMS has a long history of utilizing researchers, graduate students, and student teachers to help with their curriculum development and classroom instruction. The students in this school are accustomed to seeing secondary instructors and receiving instruction from them. This was an advantage to this project, since Swanson and one of the researchers would teach the curriculum for SCIP. We did not want our presence in the classroom to be a cause of disruption to the students, or to influence the student's progress in the project.

MVMS was also a unique school, since it is very diverse culturally and economically. The MVMS's school district reports that 48% of their students qualify for the federal free or reduced lunch program. The pre-survey we administered the first day of the project had them self-report their ethnicities; 48% reported as being Hispanic/Latino(a), 32% reported as Caucasian, 3%

[1] Swanson and MVMS are pseudonyms

reported as African American, 2% reported as Native American, 2% reported as Asian, and 13% reported as mixed race. We had a 50/50 split between female and male gendered students.

The varied student population provided a rare opportunity to test SCIP on students with different backgrounds, technical ability, and career goals. SCIP was introduced in Swanson's 8th grade science classes. She taught regular, non-honors science, which totaled 6 of the 8 science sections for the school. The students in the regular sections rated lower on standardized science testing and typically had lower academic achievement scores than the students in the honors sections. We choose not to extend SCIP to honors sections, since it involved including the other science teacher and caused scheduling conflicts for MVMS.

3.2 Project Development

The project was created after extensive discussion with Swanson about the abilities, needs, and demographics of her students. She was concerned about the home environments many of the students were faced with. Many of the higher socioeconomic students were given opportunities and access to resources that the lower socioeconomic students were not. As a result, a large number of the high socioeconomic students ended up in the honors sections and the lower socioeconomic students were in her regular sections. This achievement gap has been shown to occur across different subjects and ethnicities [2]. Swanson estimated that upwards of 70% of her students were on the free and reduced lunch program or had very similarly difficult home situations. She wanted to expose the students to different STEM careers while keeping their interest peaked. She also was adamant on giving the students freedom with the technology, so they could increase their technical skills.

As researchers, we were interested in developing and expanding on the computational thinking curriculum available to middle school teachers. We wanted to develop a small unit that a self-described luddite (like Swanson) could be comfortable teaching on their own and would be sustainable year-to-year.

We developed the computational thinking (CT) portion of SCIP by using the definitions and progression chart provided by the CSTA and ISTE in *Computational Thinking Teacher Resources* [3]. We incorporated 6 of the 9 CT skills that they list into SCIP. Here are the CT skills we included:

- *Data Collection* – The process of gathering appropriate information
- *Data Analysis* – Making sense of data, finding patterns, and drawing conclusions
- *Data Representation* – Depicting and organizing data in appropriate graphs, charts, words, or images
- *Problem Decomposition* – Breaking down tasks into smaller, manageable parts
- *Abstraction* – Reducing complexity to define the main idea
- *Algorithms & procedures* – Series of ordered steps taken to solve a problem or achieve some end

We included these skills because they fit well with the infographic project outlined by Kos and provided flexibility. These CT skills allow allowed for students to become more familiar with computers and form their own ideas about STEM careers, which aligned with Swanson's goals. These skills can also be applied across disciplines, which was favorable for Swanson and us, since SCIP was not designed to be a discipline-based project.

3.3 Timeline

SCIP was assigned at the end of the spring semester, between the end of standardized testing and the last week of school. Swanson and we considered this the most advantageous time to assign the project since there were only four weeks left in the semester and it would be difficult to fit in another lesson in that time period. This was planned to be a creative and easygoing project, to allow Swanson and the students a break from the arduous standardized testing schedule they just came out of.

These scheduling constraints allowed for a maximum 7-day project. We created the following timeline for SCIP:

- Day 1 – Introduction and Pretest. This day was broken into 2 parts: (1) Careers introduction. This taught students about the different types of training, schooling, and degrees that were available. We also talked about how much money different careers might make and what living costs are. (2) Infographic introduction. This day would introduce what an infographic was give students an idea of what was expected of them for the project
- Day 2 – Research. On this day students were supposed to pick a career and start researching it. They were required to come up with 20 facts about that career
- Day 3 – Lesson: Organization. This day was one of two lessons we would be teaching about how to create a good infographic. This lesson would cover 4 topics that would help students organize the information in their infograph: readability, consistency, creativity, and aesthetics.
- Day 4 – Lesson: Information. This was the second lesson day. This day covered how to add other types of information into an infographic, such as pictures and graphs. We would cover image copyright and different types of graphs.
- Day 5 and Day 6 – Work Day. These days were designated as students work days, so they would be working on and finishing their infographics.
- Day 7 – Presentations. This day was the final day of the project where students would be presenting their infographics in front of class.
- Day 8 – Post-test. 10-15 minutes of another class day would be devoted to the post-test for the project.

4. EVALUATION FRAMEWORK

We used Sandoval's conjecture mapping framework to organize the project goals, methods, processes, and outcomes [9]. This framework provided a systematic way to organize high-level, theoretical, and design, conjectures, the concrete embodiment of the project, mediating processes, and outcomes.

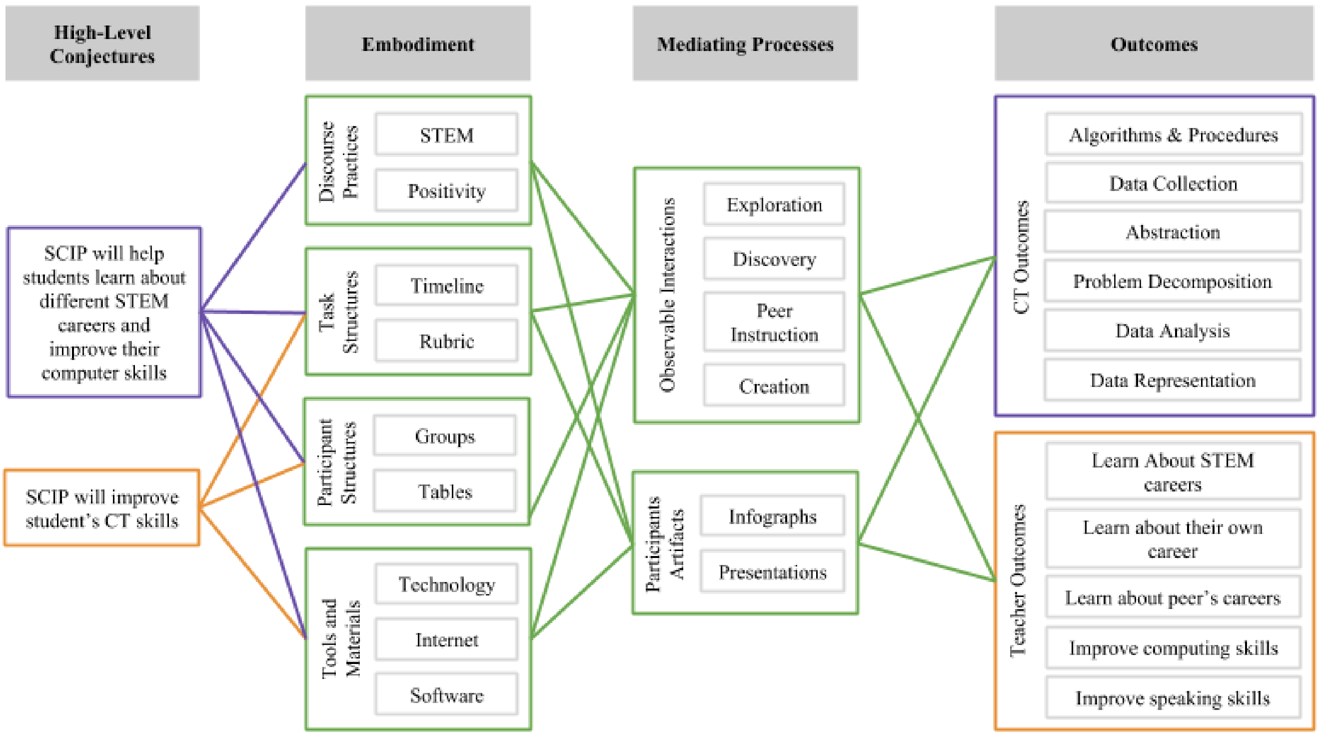

Figure 1. Initial conjecture map for SCIP.

Conjecture mapping provides a framework to organize design based methods and practices. One of the unique affordances that conjecture mapping provides is realigning project goals and conjectures. In non-design based research, projects are organized and evaluated by starting with the project goals. Instead, in conjecture mapping, the project goals are framed as outcomes and initial conjectures, or the environmental designs that describe how to support desired kind of learning, provide the groundwork for building the project.

Figure 1 shows the initial conjecture map we created for SCIP. The project's high-level goals are listed as high-level conjectures on the map; we wrote these conjectures as broad statements that the project was meant to fulfill. We also list the research team's and Swanson's conjectures. We chose not to combine these conjectures, since they had unique goals and came from two different stakeholders in the project.

The CT embodiment column of the map lists the strictures, tools, and practices we planned to use and incorporate into the project. Our choices for including these embodiments were influenced by the high-level conjectures. As the map shows, the discourse practices were the only embodiment piece that was not influenced by both high-level conjectures. This was an intentional decision on our part. From the student's perspective, the goal of the project was to research STEM careers, even though learning CT skills was a primary goal of us, the researchers, we chose not to involve an additional focus of the project.

The mediating processes column lists the interactions and artifacts we anticipated would result from the project. The observable interactions we list are conceptual in nature. Many of these were created by working with Swanson and listening to her description of how the students would move through the project.

Finally, the conjecture map lists the outcomes of the project. The outcomes are split between CT and teacher outcomes, similar to how the high-level conjectures are split as well. We also predicted that all the mediating processes would have an impact on the final outcomes.

5. DATA COLLECTION

We used a variety of methods from multiple sources to collect and retrieve data from SCIP. Since this this was a design based research project, we thought the diversity of data would help inform us about possible setbacks and successes the project was encountering on a daily basis.

5.1 Data from Students

We planned on collecting pre and post-surveys from the students as well as student work and final grades. Due to project difficulties, we were unable to administer the post-survey to the students, so we only have data from the pre-survey. Also, due to technical difficulties, we were only able to collect 92% of the student infographics.

The survey included questions that gathered self-reported data about demographics, affect towards STEM careers, and their opinions towards using computers and creating reports. Since CT was not involved as a discourse practice we were pushing, we did not implicitly survey for CT skills. Figure 2 shows a sample of the survey. Many of the questions were Likert-style questions with four responses: Strongly Disagree, Disagree, Agree, and Strongly Agree. We chose not to include the Neutral response in the list of possibilities on Swanson's recommendation. She suggested that many students do not take short surveys in class seriously, so they try to breeze through them as quickly as possible and as a result will often just answer "neutral".

5.2 Data from Researchers and the Teacher

Our research team had one researcher at the school for 7 of the 12 days of the project. They collected field notes everyday they visited the school. These field notes were from observations of the students working, reactions to teaching the material, and feedback from Swanson.

List the top 3 jobs you want after high school/college.
Job #1 ______________________________
Job #2 ______________________________
Job #3 ______________________________

I want to go to college.
Strongly Disagree Disagree Agree Strongly Agree

My family probably can't afford college.
Strongly Disagree Disagree Agree Strongly Agree

I am hopeful that I will go to college.
Strongly Disagree Disagree Agree Strongly Agree

I feel like I am a good communicator.
Strongly Disagree Disagree Agree Strongly Agree

Sometimes it is hard for me to describe what I'm thinking.
Strongly Disagree Disagree Agree Strongly Agree

I feel informed about all the different STEM careers
Strongly Disagree Disagree Agree Strongly Agree

I know about many different STEM careers available to me.
Strongly Disagree Disagree Agree Strongly Agree

Going into a STEM job sounds interesting.
Strongly Disagree Disagree Agree Strongly Agree

I do not think that a STEM career is for me
Strongly Disagree Disagree Agree Strongly Agree

STEM careers sound boring.
Strongly Disagree Disagree Agree Strongly Agree

Going into a STEM job sounds fun.
Strongly Disagree Disagree Agree Strongly Agree

I am interested in other types of careers, not STEM careers
Strongly Disagree Disagree Agree Strongly Agree

I am not smart enough for a STEM career
Strongly Disagree Disagree Agree Strongly Agree

I'm not really interested in STEM jobs.
Strongly Disagree Disagree Agree Strongly Agree

Figure 2. Partial student survey.

6. DEPLOYMENT

We deployed SCIP during the 4-week period from mid-April to mid-May. The school we were working with was on a block schedule, which meant the students were only scheduled to come to class every other day. We will refer to these alternating days "A" and "B" days.

When running the project, we encountered many successes, challenges, and setbacks that changed the design of the project. Many of these events occurred when we were stitching from the embodiment stage to the mediating processes stage of the conjecture map or from the mediating processes stage to the outcome stage. In this framework, Sandoval calls these shifts between stages design conjectures and theoretical conjectures, respectively.

6.1 Design Conjecture Events

Many of the setbacks we encountered in SCIP came from this stage. The students, Swanson, and we had many difficulties with the tools and timeline we chose for the project.

6.1.1 Tools

When we first conceptualized the project, we planned on using Piktochart.com, a free infographic generator website. Swanson offered to take the class to the computer labs daily, so the students could access the website and create their infographics online.

As the start of the project came closer, we were informed that school would enter a "technology blackout" during the project. This year, standardized testing had moved from a paper to online versions and MVMS administers chose to lock down all laptop carts, computer labs, and Internet access. The students and Swanson were able to access the Internet at this time through use of their district provided IDs, however the on-site researcher was unable to use the Internet for the duration of the project.

Due to computer unavailability, Swanson suggested that we use the student's iPads instead of computers. MVMS was a pilot school for a district-wise initiative to give every student access to an iPad Mini. We chose to move forward with the iPad Minis, however this opened up a wealth of additional problems that we did not plan for at the beginning of the project. Our first choice for online infograph creation, Piktochart.com, was not iPad compatible, we were forced to use an installed app, Easelly, instead of a website.

This app did not have the same functionality as Piktochart and limited the students in what they could create for their final infograph. The app also had numerous bugs that were difficult to work around, especially for students with minimal computer experience.

Some student chose to bring in their personal laptops and use Piktochart.com instead of the Easelly app. This was an innovative solution on their part and Swanson encouraged the students to solve problems with the app in different ways. However, this caused a clear digital divide between the students in the class. The on-site researcher saw certain students how brought in their personal laptops sitting together and the students who had to use the iPads sitting together. The researcher noted that this was due to practically reasons, students using similar software were able to help and assist each other in creating their infographics; however, this also created a divide in the class between the privileged, laptop-owning students and the iPad users.

On the final presentation day, the students were supposed to email their final version of their infographic to Swanson and she would let them present from the classroom's computer. Many students were able to email Swanson their infographics, however, some students has parental restrictions on their email accounts, which restricted them from sending emails with image attachments.

Swanson let those students present their infographics directly from their iPads, so they were still able to participate in the class activities. The on-site researcher then helped those select students download their infographics and send an email to Swanson by using another account; however they were unable to complete this process with all the students, which caused us to miss 8% of the final student infographics.

6.1.2 Timeline

Due to the timing of this project, we ran into multiple, unavoidable scheduling conflicts with this project. Day 1 of the project coincided with Take-Your-Child-To-Work Day, and even we did not plan for. This caused us to remove an entire day from the 7-day project and combine the activities for Day 1 and Day together. This did not allow us to spend as much time on the activities of these days as we wanted to and say that the students suffered because of it. We still administered the pre-survey on this day, since it was still of official start of the project and we kept the careers introduction as we originally planned. The careers lesson was extremely important to Swanson and us, so we did not alter the lesson in anyway and kept with the original timeframe. We moved introduction to infographs to the second day of the project, which was Day 3 on the original timeline, simply because we did not have enough time to cover this material on the first day. Originally we had Day 2 of SCIP as a research day, where the students were able to spend time researching and looking up facts about their career. We kept this activity on this day, but the students had a limited amount of time to conduct the research and were required to finish anything they did not get done in class as at home.

Throughout the remaining 5 days of the project, there many other events that overlapped with the project. Some of these events were fire drills, late start days, field trips, standardized testing, re-take standardized testing, band and orchestra practice, and the school play. Each of these events did not affect the entire project like the take-your-child-to-school day did, because they were usually limited to a single class period. Overall, this did not affect the timeline of the project, but it did cause problems keeping the students on track. We were given a strict time frame for the project deployment and designed the project with a micromanaged timeline. On the days where an unplanned event would come up, Swanson and the on-site researcher struggled to find ways to keep up the pacing of the project so all students were consistently at the same level.

The final scheduling conflict, which had the greatest impact on the project, came after the project ended. We scheduled the post-survey the day after the project ended, so the students would have time to reflect on what they learned after their peer's presentations. This day was also the last day of regularly scheduled class for MVMS and the science teachers were doing a competitive egg drop for the entire 8th grade. The guidance counselors informed Swanson the day before the egg drop that they needed 30 minutes of class time to go over high school planning with the students[2]. Since this last day of class was overburdened with these three activities, Swanson decided to not administer the post-survey to the students and instead let the counselors speak and moved directly into the egg drop. Due to SCIP occurring at the end of the school year, we were unable to administer the post-survey at another time and lost this potential data.

6.2 Theoretical Conjecture Events

Since we were unable to collect post-survey data from the students we do not have a mechanism to tell whether the students achieved the learning outcome from the project. The on-site researcher was able to collect student observations for the days they were present in the class and we have student infographics that we will use to student interest. We are acutely aware that the data we have provides a limited view of student learning and outcome success.

6.2.1 CT Outcomes

The CT skills we chose to include in this project manifested in the most direct way in the project timeline. Each day during the project was devoted to one or two of these CT skills. As mentioned before, we chose to leave the CT skills as hidden project goals and did not reveal them to the students. This caused some tension within the project, since sometimes students would be looking for more instruction or direction on an activity and would not realize that the process of creation their own instructions or directions was another part of the activity. For example, Day 4 – Lesson: Information correlated with the CT skill Data Representation. On this day the students had to collect the data and facts they found about their career and compile them into graphs and charts. Most of the students kept asking for direct and exact instructions about what data to include in the graph and what kind of graph they had to make. Swanson and the on-site researcher gave examples of the types of graphs the students could make and provided information about the purpose different types of graphs have, however they never gave the students direct instructions for the kind of graph they had to include in their infograph. This frustrated many students and did not provide a positive learning environment. The final infographs showed that most of the students included graphs that mimicked Swanson's examples and were not original in their content.

6.2.2 Teacher Outcomes

Half of Swanson's goals, listed on the conjecture map as "Teacher's outcomes" were not able to be fully achieved because of the switch from computers to iPads. When we planned this project, she emphasized learning computing skills, however, many of these skills were dependent on a literal computer and not a tablet. The students were able to improve their iPad skills through this project, however they had be using the iPads throughout the school year on various projects, so this project was not able to have as large of an impact as originally planned.

Swanson's other goals were about improving a student's knowledge of STEM careers. Throughout the project, we saw that this outcome was achieved through a variety of ways. On Day 1 of the project, we broadened the student's definition of STEM to include vocational and apprenticeship jobs. The field notes from that day notes that the students were very engaged with this lesson and kept asking questions about specific careers and how they could get involved in them. Many of the student who asked questions in class about specific careers also chose that career for their infographic. Many of the lessons we covered on the first day were also mentioned again in the student's infographic.

One result we did not anticipate from SCIP was students choosing similar careers based on their proximity to each other. We saw a similar pattern across multiple classes. Students sat together in tables of four and many of these groups chose careers in similar

[2] In this school district 8th grade is the last year of middle school and 9th grade is the first year of high school.

fields. We had groups of students choose careers that involved sports (such as sports medicine, personal trainer, or sports newscaster), animals (animal trainer or veterinarian), or medicine (nurse, dental assistant, or radiologist). One of the project outcomes was for students to learn about different careers by proximity. We allowed them to work in groups to encourage the spread of ideas. The student groups who had similar careers were the students who learned the most about their own career and their peer's career. We say them sharing resources, helping each other create their infographics and even making comments during each other's presentations. In one class, we had two female students who chose a nurse and a nurse practitioner careers start a dialogue between themselves and Swanson about the difference between these two jobs, an experience they would not have had if they had not worked together.

7. DISCUSSION

SCIP was gifted with many successes and burdened with many challenges. We still see this project as a viable Computational Thinking unit for middle school students. Swanson was especially enamored with SCIP, since it provided a CT project that did not require her to learn programming or other computer science concepts like many other CT projects she has looked at in the past. We were all excited about the content of the project as an outreach project for students to learn more about STEM careers in a creative way. We are also big proponents of the project design since it provides a way for underrepresented students to learn more about a field that they may not have exposure to at home or culturally. The project does not coddle these students and provides an interesting way to learn about STEM for students of all backgrounds.

7.1 Revised Project

Based on the observations and events we encountered throughout the project, we have a revised project outline:

Day 1 – Introduction: Careers and Pre-test

Day 2 – Introduction: Infographics

Day 3 – Research – Data Collection and Data Analysis

Day 4 – Lesson: Organization – Data Representation

Day 5 – Lesson: Information – Problem Decomposition

Day 6 and Day 7 – Work Day – Abstraction and Algorithms & procedures

Day 8 - Review – Abstraction and Algorithms & procedures

Day 9 – Presentations and Post-Test – Abstraction

We have kept much of the original project outline, with the exception of adding two additional days. We chose to add "Day 2 – Introduction: Infographics" to give the students more time to play around with the infographic software and get a handle on what infographics are before they are required to make one for the project. We have also added "Day 8 - Review – Abstraction and Algorithms & procedures". This day will be a review day for the students, where they can get feedback on their infographics from their peers. We are hoping this will encourage the students to work together and learn more about each other's careers. This day also adds in an extra padding day, so the schedule will not be so strict and students will not have as much of a chance to fall behind due to other scheduling changes. We have also moved the post-test to the last day of the project and not after the competition of the project.

Swanson is still enthusiastic about SCIP and plans to do the project again in the fall of 201 with her new students. She will be using the revised curriculum for this next iteration of the project. She is also hoping that the shift from spring to fall semester will relive some of the scheduling problems we encountered in previous iteration. We plan to follow up with Swanson after the conclusion of this iteration of SCIP.

8. ACKNOWLEDGMENTS

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