Cataloging Lesson Plans Developed by Pre-Service Science Teachers During a Summer Research Experience

A Senior Project

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Bachelor of Science

by

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1. Abstract

This study is modeled after the senior project "Teachers Who Conduct Research and their Ability to Apply their Experience to Lesson Plans" by Cal Poly student Megan Ziegler and includes an independent analysis of the 2011 and 2012 lesson plans that participants in the STEM Teacher and Researcher (STAR) Program developed as part of their summer research experience. At the end of the STAR summer research program, STAR Fellows are required to submit lesson plans. During Spring Quarter of 2012, I had the opportunity to catalog lesson developed during Summer 2011. Later in Fall Quarter of 2012, Cal Poly undergraduates Megan Ziegler, Emmy Trieu, Anne Welker, and I, along with STAR Program Director Bryan Rebar, decided to continue this research and work together to catalog the lesson plans that STAR Fellows developed in Summer 2012. In my analysis of the data, I found that STAR program participants included more aspects of their research in their lesson plans in 2012 than in 2011, and that certain NGSS practices were used more than others.

2. Introduction

The STEM Teacher and Researcher (STAR) Program is a summer research opportunity for science, technology, engineering, and mathematics (STEM) majors who aspire to teach science and math in grades K-12. It is designed to get them thinking about what teaching tools and techniques they could incorporate into their own lesson plans to better prepare their potential future students for college-level research (Baker and Keller, 2010). Using an adaptable, recorded protocol, the purpose of this report is to categorize the lesson plans that participants developed in the STAR Program based on unique research connections that strengthen STEM education through authentic research. The first time I did this was for 2011 lesson plans and I did not see a strong correlation between the research and the planned lesson activity. However, based upon this finding, 2012 STAR Fellows were given more explicit instructions about connecting their research to their lesson plans and were provided a summary of ways to build these connections. The goal of this report is to determine the effect of that intervention.

3. Protocol and Methods

3.1 2011 Lesson Plans

I was given no guidance or bias as to what I should use as categories in 2011, whereas some were given to us in 2012 and we were allowed change them as much as we wanted to as long as we all agreed on the changes. My goal in developing the 2011 categories was to connect the research practices the aspiring instructors used in their 2011 STAR summer research projects to the education practices they decided to write about using in their lesson plans at the end of the summer research program. These are the 2011 categories I submitted at the end of Spring Quarter 2012, and were provided to the 2012 STAR participants as guidance for writing their lesson plans:

- Students collect their own data in the classroom using **similar materials and equipment** as the instructor used in their summer research project.

- Students collect their own data in the classroom using **completely unrelated materials and equipment** to simplify and demonstrate concepts the instructor used in their summer research project.

- Students/instructors **supplement the lesson** with additional information through either the use of the internet, a PowerPoint presentation, or a projector.

- Instructors teach the students how to analyze data using the same **computational software** they used in their summer research project.

- Students present their thoughts and ideas to the rest of the class in groups **with the use of a visual aid** (i.e. Whiteboards).

- Students present their thoughts and ideas to the rest of the class in groups **without the use of visuals aids**.

- Students record their thoughts and/or results in a **lab notebook**

- Students record their thoughts and/or results in a **worksheet**

- The Instructor stresses the importance of **safety** with the materials the instructor used in their summer research project, and the materials the students will be handling in the lesson plan.

- The goal of this lesson plan was to teach the students new **vocabulary** that the instructors used in their summer research project (i.e. math=compressed data)

- The goal of this lesson plan was to focus on the societal **relevance**, and get the students excited about the implications of the lesson plan (i.e. cancer, ecology)

- The goal of this lesson plan was to get the students thinking about exactly how much the materials cost and to stress the importance of financial management

3.2 2012 Lesson Plans

During the 2012-13 academic year, our research group decided to base our research protocol on the research protocol established in the book *Qualitative Data* by Carl Auerbach and Louise B. Silverstein. The text states that research is valid when multiple researchers to come up with similar results after they agreed to follow a specific, recorded protocol while they independently sort the same data set. When this occurs, it is called inter-rated reliability. These protocols are the protocols Megan, Anne, Emmy, and I agreed to use for cataloging the lesson plans from 2012:

1. To design a coding rubric that uses eight categories that we based off of the eight Scientific and Engineering Practices from the National Research Council Framework.
2. To individually read and code biology lesson plans using this initial coding rubric.
3. To meet with our senior project supervisor, Dr. Rebar, and at least one other of the three researchers every other week to compare our results and discuss any changes we wanted to make to the protocol as a group. Because our schedules conflicted, we were not all able to meet at the same time at any time during the week.

4. After the fifth week of cataloging, we decided as a group that the way we were having our discussions in pairs of two wasn't working and that we would try to continue our discussions online using Google Docs. The comment function allowed us to keep track of and share our thoughts with each other.
5. To revise the categories in the initial coding rubric into subcategories – a diverging technique described in *Qualitative Data*.
6. To individually read and code the remaining lesson plans off of the new coding rubric.

The outcome of the coding effort described above, is presented below in the Results section. When I met up with Bryan Rebar a quarter later to talk about my last quarter of my Senior Research Project, he told me that he would like me to review Megan's analysis of the our data in her senior project and to expand upon it. They had decided that the practices we used in the previous quarter were too specific to clearly answer the question they were trying to answer at that time, which was: did the STAR summer research program improve the ability of the participants to teach STEM education and write challenging, exciting STEM lesson plans? They also decided that the best way to determine this was if they categorized the data by their unique connections between the lesson plans and the corresponding summer research projects.

Table 1: Unique Connections

Unique Connection	**Criteria**	**Example Lesson Plans**
Used STAR Data	- Students analyze data collected in the summer research project (SRP) in the lesson plan.	Uses the data on sea star population densities collected in the SRP.
Used the Same Methods for Data Collection	- Students use the same procedure, or a very similar procedure, as the researcher did in the SRP in the lesson plan.	Same: Has students develop primers for certain genes using the exact same procedure used in the SRP. Similar: Pharmacokinetic ADME model developed in SRP, and used in the lesson plan.
Studied the Same, Specific Concept	- Students cover a specific concept in the lesson plan that the researcher's SRP also focused on. - Teacher directly mentions or discusses the SRP in relation to the lesson plan.	Pharmacokinetic ADME model developed in SRP, and explained in the lesson plan. The lesson plan and the SRP studied the effect of pharmaceuticals on waste water and wildlife, and the teacher discusses their research in detail. Simply discussed their lesson plan, after they used real data collected in the STAR program.

Developed their own Procedure	- Students devise their own experiment with very little guidance from the teacher.	Mimics authentic research instead of just being a traditional "cookbook" lab by having the students design their own procedure with only a clear objective in mind.

The unique connections in Table 1 were defined the same way as they were in Megan's senior project. That is, we looked for lesson plans that only teachers who had participated in the research experience would be able to make. For instance, one STAR Fellow had his students model the research process instead of just having them do a traditional lab, better preparing the students to go through a similar research experience as he did. His lesson plan is designed to get students critically thinking in a way most conventional labs do not. Megan did not feel that this constituted a unique connection, because she felt as if anyone could have written the lesson plan. I see how anyone could teach lesson plans like this, but most teachers don't. The STAR Fellow and many other participants in the STAR program seemed to think about how to best prepare their students for college-level research more than other teachers, which to me is a unique connection. The first and second categories are fairly self-explanatory, because other teachers would not have access to all of the data they collected or the procedures they used in their summer research project. The third category is the broadest, and a combination of two of Megan's categories: "discussed their research" and "researched same focus organism or concept." Lesson plans that fulfilled both of Megan's categories as well as either category were all included in my third category.

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Megan chose to look at all the lesson plan from 2012, whereas I only chose to look at smaller samples of lesson plans from 2011 and 2012. I chose to look at smaller samples initially because I felt that Megan's results were too specific to biology, the subject area she started cataloging with and majored in. Megan initially divided the lesson plans into subject areas, so that she could later compare the subject areas to each other. I believe this had a significant impact on the names and criteria of her unique connections. I wanted my categories to be more general and applicable to all of the lesson plans from both years. In order to accomplish that I randomly selected two lesson plans from each subject area in 2012 and wrote down the unique connections they either mentioned or I identified, using a similar approach to the one outlined in Megan's senior project. Two out of my initial four categories were very similar to two of Megan's. The other two were similar, yet still clearly different as described below.

4. Results

4.1 NGSS Practices

Anne reported the percentages of total lesson plans (n=38) which included a NGSS practice in her senior project, "Relationship between future teachers' research experience and development of lesson plans that feature scientific and engineering practices," but did not mention the subcategories in her analysis. I thought that since we spent so much time defining the subcategories as a group that we should also report their corresponding percentages of total lesson plans (n=24). These results are summarized in Table 2 below. Anne looked at more lesson plans for the general practices, because we never sorted the 14 Biology lesson plans by these subcategories.

Table 2: NGSS Practices and Subcategories

Practice	Subcategory	Description	Example	Percentage
1. Asking Question and Defining Problems	T1	The teacher asks leading questions to get students to formulate their own scientific questions.	In the lesson plan titled, "Where do plants get their mass?" the teacher asks a leading scientific question "What do you think was different in the way these [plants] were grown?" Students then come up with their own specific questions related to the original, broad, question.	27%
	T2	The teacher gives explicit scientific question that students will test.	In the lesson plan titled, "Pharmaceuticals in Wastewater and Caffeine's effect on Daphnia", the teacher asks students "How do drugs that people take affect other organisms?" The teacher then talks about specific research for that scientific question.	44%
	S1	The students carry out an investigation from a scientific question which they ask.	In the lesson plan titled, "Where do plants get their mass?" the students come up with their own questions related to plant growth and carry out the investigation.	4%
	S2	The students practice asking scientific questions, but do not complete an experiment that relates.	In the lesson plan titled, "Using Leatherback hatchling data to develop the skills of creating and testing a hypothesis with data", the students are asked to come up with a future research question, but do not actually carry out an investigation.	8%
2. Developing and Using Models	S1	The students develop models from given or experimental data.	In the lesson plan titled, "Food Web Fun," students are given cards with descriptions of organisms and their eating habits. Using the information given about each organism, students then create a food web, which is a model of the energy transfer between organisms in an environment.	6%

	S2	The students use existing models to understand and/or explain related information.	In the lesson plan titled, "Where Do Plants Get Their Mass?" the origin of plant biomass is determined experimentally and also by using the model of photosynthesis. An attached student worksheet tests student knowledge on the two reactions of photosynthesis and requires a concept map linking photosynthesis to another process, respiration.	50%
3. Planning and Carrying Out Investigation	S1	The students have control over planning of experiment and then carry out the procedure.	In the lesson plan titled, "Bomb Calorimetry", students use the provided materials to come up with a calorimeter to test the amount of Calories in various foods.	33%
	S2	The students plan an experiment, but do not carry it out.	In the lesson plan titled, "Using Leatherback hatchling data to develop the skills of creating and testing a hypothesis with data", the students are asked to come up with a procedure for determining "What 50differences might exist between hatchlings of the first emergence and those of later emergences or are excavated out?"	6%
	S3	The teacher plans the experiment and gives students a written procedure to follow.	In the lesson plan titled, "How do Dietary Components Affect Growth?", students are assigned one of three procedures to test the relationship between dietary supplements and plants/animals.	50%
4. Analyzing and Interpreting Data	S1	The students do all analysis of raw data with little to no guidance from the teacher.	In the lesson plan titled, "Learning the 'Scientific Method' Basics," the students use the data from their own procedure to determine which reagent is the cause of each physical or chemical change. Students are responsible for all of the analysis.	35%

	S2	The students follow specific instructions from teacher for the analysis of raw data.	In the lesson plan titled, "Density Comparison of Water and Ice," teacher provides the density calculations that the students must use to determine the density of the ice and the water in their experiment. The teacher doesn't provide an opportunity for students to figure out their own analysis.	38%
5. Using Mathematics and Computational Thinking	Sa	The students use graphs or charts to display data. Can be hand drawn or created electronically.	In the lesson plan titled, "Density Comparison of Water and Ice," the students, for the "Extend" portion of the lesson, must use graphs to explain relationships from a Buoyancy online tool.	40%
	Sb	The students use given equations and perform other calculations to analyze data.	In the lesson plan titled, "Mission--Solve the Energy Crisis and Save the Planet," students use the given thermochemistry equations to determine the energy output of various fuels from a calorimeter. Math is required to analyze the data that they obtained.	21%
6. Constructing Explanations and Designing Solutions	S1	The students construct explanations from experimentally-obtained data (student-performed).	In the lesson plan titled, "Pharmaceuticals in Wastewater and Caffeine's effect on Daphnia" students individually explain their results to the rest of the class.	54%
	S2	The students construct explanations from given experimental data.	In the lesson plan titled, "Where did the Seastars Go?" students are given data on where seastars were located and how many of them there were and then the students were asked to construct an explanation as to why the seastars were located where they were.	15%
7. Engaging in Argument from Evidence	Sa	The students argue a point with individual writing, such as explaining results in the		38%

		conclusion of a lab report.		
	Sb	The students orally explain reasoning behind a statement derived from evidence.		35%
	Sc	The students write a conclusion with arguments as a group.		21%
8. Obtaining, Evaluating, and Communicating Information	Sa	The students obtain information. Can be through a variety of means, including web research and textbooks.		13%
	Sb	The students evaluate information either given or found to determine its usefulness and/or reliability.	In the lesson plan titled,"Apply your Genetic Knowledge: Help Conserve Marine Life" students score 120 electropherograms provided by National Oceanic Atmospheric Administration labs.	29%
	Sc	The students communicate information, either in writing or orally.		71%

The percentages of the 2012 lesson plans that included our NGSS subcategories, reported in Table 2, agree with Anne's reported percentages from her senior project of the 2012 lesson plans which included NGSS practices, presented in Table 3 below. The most abundant subcategories in Table 2 are consistent with the most abundant practices in Table 3, like practices 3 and 8, and the least abundant subcategories are similar to the least abundant practices in Table 3.

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Table 3: Anne's NGSS Practices Percentages

Practice	1	2	3	4	5	6	7	8
Anne's Percentage	58%	61%	79%	74%	47%	63%	71%	92%

4.2 Unique Connections

Both Megan and I identified four categories of unique connections and the same average number of connections per lesson plan in 2012, which is shown in Table 4. This may indicate

that the sample size of lesson plans I choose to analyze reached a saturation level, indicating that it was sufficiently big to reveal the same trend in the 2012 lesson plans as Megan's analysis.

Table 4: Comparison of the Data

Group of Lesson Plans (n)	My Average of the 2011 Lesson Plans (14)	Megan's Average of the 2012 Lesson Plans (37)	My Average of the 2012 Lesson Plans (14)
Average Number of Connections per Lesson Plan (out of 4)	1.14	1.42	1.42
Used Real Data Collected in STAR	21%	18%	14%
Used Same Procedure	21%	27%	57%
Discussed their research	N/A	29%	N/A
Studied the same, specific concept	21%	60%	43%
Developed their own Procedure	50%	N/A	29%

5. Discussion

The percentages in Tables 2 and 3 were calculated by taking the number of times a category occurred divided by the number of opportunities it had to occur. The number of opportunities to occur was determined by multiplying the number of lesson plans examined, n, by the number of researchers who sorted that data set. For example I looked at data we collected as a group of all the lesson plans from 2012 to calculate the percentages in Figure 2, just as Anne had with NGSS practices. The sum of the percentages of a NGSS practice's subcategories is not supposed to add up to the percentage of practice in Table 3, because two or three subcategories sometimes fulfilled the same practice. In other cases, like the fourth NGSS practice, the subcategories are exclusive. The sum of subcategories 5.Sa and 5.Sb percentages, which is 61%, is still less than the sum of subcategories 4.S1 and 4.S2 percentages, which is 73%. This is to be expected from largest and smallest percentage of 2012 lesson plans which included a NGSS practice in their senior project reported in Anne's senior project.

Megan and I defined the unique connections we saw independently, and yet we saw very similar results. Some of my unique connections were broader than Megan's, and others were more specific. For example, I saw more lesson plans fitting into my "Used the Same Methods for Data Collection" category than Megan's "Used Same Procedure" category, which is obviously defined to be much broader, and Megan saw more lesson plans fitting her "Same focus concept or organism" category than I saw for my "Studied the same, specific concept" category. This was an arbitrary difference, because each of our broader categories could be divided into two more

specific categories and we saw the same total number of connections being made. I considered the lesson plans that fit mostly into Megan's "Discussed their research" and "Used Same Procedure" categories to fit into my "Used the Same Methods for Data Collection" category. There was a big increase in the abundance of my "Used the Same Methods for Data Collection" and "Studied the same specific concept" categories from the 2011 lesson plans to 2012 lesson plan, and a decrease in the abundance of my "Developed their own Procedure" from the 2011 lesson plans to 2012 lesson plan. The overall result was a clear increase in the average number of unique connections out of four connections per lesson plan from the lesson plans written in 2011 to the lesson plans written in 2012.

6. Benefits of Further STAR Research

Cataloging lesson plans written by the Fellows participating in the STAR program is an extremely useful experience for a future prospective science teacher to have, and I would urge other prospective science teachers to continue to develop this initial research. As a future prospective science teacher and a physics major, it was interesting for me to see how the physics lesson plans modeled their research with less direct examples than the other science subjects' lesson plans. I was not too shocked by this, because, as a physicist, I already knew from my classes in college that most of the modern research that physicists are working on today is extremely complicated and perhaps too challenging for students in high school to comprehend with only a basic understanding of modern physics. However, reading all of those lesson plans did get me thinking, as an aspiring science teacher, about the kinds of lesson plans I could one day teach in my classroom to help prepare my students for similar research opportunities -- not just in physics, but other science subjects as well.

It is very important for other students to continue researching the lesson plans produced by the STAR program in order to either validate or discredit the claims of my analysis of these results. Since Megan and I both saw an average of 1.42 unique connections per lesson plan in the lesson plans from the summer of 2012, I would be most interested in seeing if another student could reproduce similar results from the same data, using the same protocol as we did. It would be interesting to see if other students could also see if there was a clear increase in the number of unique connections per lesson plan from 2011 to 2012 as I observed, or if they could catalog the 2011 lesson plans using the NGSS practices or subcategories we established for the 2012 lesson plans. Of course, I know from experience that all of this would be too much to ask from a single researcher, and if more researchers agree on a finding, then the finding is more valid. It is essential that they keep their analyses independent, which I found easiest to do when I worked on my senior project a different quarter from Megan and Anne. That way, our senior project mentor was able to give me more specific guidelines based on Megan and Anne's findings. The first quarter we all worked together we were all going in different directions with different ideas, and what we were actually trying to accomplish week-by-week changed frequently. As a result we got a lot of data, but it was a very confusing process. With that being said, everyone involved in that experience, including myself, now have a much better understanding of college-level research.

7. Conclusion

The goal of this report was to determine the effect of the decision to give STAR Fellows more explicit instructions on how to connect their research to their lesson plans in 2012 and to provide the Fellows with a summary of ways that I saw the 2011 lesson plans make connections as well as a copy of the NGSS practices. I found that that the aspiring new teachers who participated in the 2012 STAR summer research program tended to use NGSS practices 3 and 8 a lot more frequently than they used NGSS practices 1 and 5, and that there was an increase in the average number of unique connections per lesson plan from the lesson plans developed by the STAR program during the summer of 2011 to the lesson plans developed in 2012. I found these results by sampling lesson plans developed in the STAR program in 2012 and 2011, and analyzing the data separately from Anne Welker, Emmy Trieu, and Megan Ziegler.

8. References

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