Creating Opportunities for Reflection: Analyzing Middle School Student Work During a Service-Learning Course on Solar Cells

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Abstract - The purpose of this study is to describe how analyzing student work can be used to help undergraduates reflect on the effectiveness of their service-learning experiences. The service-learning collaboration between a university and middle school was designed to increase undergraduates’ and middle school students’ knowledge of solar energy. Three undergraduates enrolled in a service-learning course that covered basic solar energy concepts and formative assessment instructional strategies. The focal point of the course was the implementation of several activities in a middle school classroom that addressed middle school students’ misconceptions about solar energy, such as the amount of solar energy production at low temperatures or on a cloudy day. Data from this study includes student work during a small-group activity on solar cells. Findings suggest that undergraduates can analyze student work and use this information to better understand how their efforts can influence middle school student learning of solar energy.

Index Terms: STEM, Engineering, K-12, K-12 Outreach

INTRODUCTION

Opportunities for reflection are a key component of effective service-learning programs. Rogers draws on John Dewey’s work to describe reflection as “meaning-making process that moves a learner from one experience into the next with deeper understanding of its relationships with and connections to other experiences and ideas”. Reflection can positively influence a range of outcomes, including undergraduates becoming more aware of themselves as teachers and learners and encouraging their extended connection to serve others.
It is widely assumed that without reflection, the service-learning experience alone will not be as beneficial for undergraduates [13-15]. There are different strategies to facilitate reflection opportunities among undergraduates such as directed readings, structured discussions, or directed writing [16 17 18 19 20]. Writing a journal, for example, “enables students to practice basic writing skills, analyze service situations, evaluate their own actions and reactions…[and] take maximum advantage of the opportunities for personal reflection and self-evaluation that service-learning experiences elicit” [21].

Reflection of service-learning in engineering education is well-known [3,22]. This paper describes reflection of service-learning in engineering education in a K-12 setting through the analysis of middle school student work [23-25]. The information gained from analyzing student work can provide information about student understanding. It can also be used to inform teaching and, ultimately, student learning [24,26]. Student work in mathematics, for example, might indicate that the student found the correct answer but used incorrect reasoning to do so. Conversely, student work in mathematics might provide evidence of an incorrect answer but a correct approach or strategy to solving the problem. This information can be used to modify instruction and improve opportunities for student learning.

This paper describes a service-learning course that provided opportunities for undergraduates to analyze middle school student work on solar energy as a form of reflection. Evidence of student learning was collected and analyzed. The procedure described in this paper centers on one of those opportunities in which analyzing student work helped to facilitate focused discussions on behavior that could improve undergraduates’ future interactions with middle school students.

METHODS

Sample
An eighth grade teacher volunteered to participate in a university-based service-learning project. The teacher was part of a professional development program for middle and high school teachers that provide opportunities for students to participate in hands-on mathematics, engineering, and science competitions. The teacher was part of the program for two years prior to this project. She was interested in learning more about solar energy and wanted to start a model solar car design project with her students.

All of the students included in this study elected to be in science and mathematics classrooms that focused on engineering design tasks. Students applied to be in these classrooms and committed to spending time to participate in these design projects and learn grade-level specific standards on their own time. The middle school students and teacher did not receive any monetary compensation for their participation.

The teacher and her students attend a middle school with 910 seventh and eighth grade students, of which approximately 80% are Hispanic, 35% are designated as English Language learners, and 76% are eligible for free or reduced priced meals [27]. The school has a 2009 academic performance index (API) score of 4. The API is a decile rank from one (lowest) to ten (highest) based on student performance on standardized achievement measures in Mathematics, English-Language Arts, Science (grades five, and eight through eleven), and History-Social Science (grades eight through eleven).
Measures

Data was collected from a sample of eighth grade students from a single classroom. Prior research indicates significant increases in student knowledge around solar cells on a written assessment and individual interview. Data included in this particular paper includes student work from a small-group activity on solar cells (N = 37). Students worked in small groups on solar cell activities focused on how the amount of energy varies under different temperature conditions. The following materials were included in the test setup: solar cell (2.2V, 50mA, 31mm x 31mm x 3.0mm), flash light, ring stand, two clamp holders, extension clamp, extension ring, multimeter, hair dryer, hand warmer, and ice pack (Figure 1). Students measured and recorded the current generated by the solar cell under six different conditions (flashlight on, standard room temperature; flashlight off, standard room temperature; flash light off, hair dryer; flash light off, hand warmer; flashlight off, ice pack; flash light on, ice pack). The handout provided space for students to record their findings and respond to five short response questions on how temperature affects the amount of energy produced.

![Example Test Setup](image)

**FIGURE 1**

**EXAMPLE TEST SETUP**

Note. The solar cell, hair dryer, hand warmer, and ice pack are missing from this figure.

Procedures

*Undergraduate service-learning course.* Three undergraduate students (one junior engineer major, one senior biology major, and one senior mathematics major) were selected to participate in a ten-week, undergraduate service-learning course. The course was led by an engineering professor and an education professor. Undergraduates received course credit for participating in
the course. The course was designed to provide learning opportunities for both the undergraduates and the middle school students. Directed readings and lectures provided content knowledge on solar energy along with teaching and assessment strategies. The focal point of the course was the implementation of three visits to a single middle school classroom. The first visit provided an overview of solar energy through a whole class discussion and activity. The next two visits (approximately one week apart) consisted of two different activities in small groups that addressed the middle school students’ misconceptions about solar cells, such as the amount of solar energy production at low temperatures or on a cloudy day. The activities were also designed to relate to several of the eighth grade California Content Standards29. By the end of the three visits, the middle school students were expected to know that solar cells are used as a power source, solar cells convert light to electricity, solar cells generate power by absorbing radiation, and the amount of light absorbed by the solar cell can be impacted by a variety of factors.

There were numerous opportunities for students to reflect on their service-learning experience throughout the course. For the first five weeks of the course, students were given specific prompts to guide their reflections. They digitally recorded their reflections and uploaded the audio files to the course website. The instructors listened and commented on each reflection and talked about major themes across the reflections at the beginning of each class. The reflections included questions about learning, for example, “How do you know when someone has learned something?” and “How can you influence learning?” along with questions about solar energy, such as, “How would you describe to a middle school student how a solar cell works?” These reflections were intended to prepare undergraduates for implementing the solar cell lessons at the middle schools. During and after the implementation of the lessons (the last five weeks of the course), the undergraduates were provided opportunities to reflect on the middle school students’ assessment and interview data. This was an informal process in which the two instructors asked undergraduates to provide general statements about what they could conclude about student knowledge of solar cells from the evidence. In addition, a more formal process of analyzing student work was carried out as a way to help the undergraduates reflect on student learning.

Analyzing student work. To analyze student work, a single, dichotomous score was created for each student. This score was based on whether or not students provided an accurate relationship between the current generated by the solar cell depending on the temperature of the solar cell. Students were asked to support their answers to the question of whether the current generated by the solar cell depends on the temperature of the solar cell. If students incorrectly indicated that different temperatures lead to different amounts of power generated, or that the heat influences the amount of current generated, they received a “0.” Student responses that were ambiguous or incomplete were also scored a “0.” If students indicated that different temperatures did not lead to different amounts of power generated (temperature doesn’t matter), they received a “1.” After scoring student work, undergraduates individually wrote brief reflections about how this information fit within their conceptions of what the middle school students understood. These reflections were then shared with the whole group.
RESULTS

Scoring Student Work

The undergraduates were fairly consistent in their scoring of student work. The dependability of the scoring procedures was investigated using generalizability theory\(^\text{30}\). Generalizability theory estimates the magnitude of multiple sources of error and provides a reliability coefficient for the proposed use of the measures. Students were the object of measurement. There was one source of variation that contributed to errors in measurement: the undergraduate raters. The undergraduates were provided with a rubric for scoring, which included example student responses and descriptions of how to interpret and score those responses. All three raters scored all of the student work. Findings from the generalizability theory model confirmed the lack of variability due to raters. Less than 1% of the variability was due to differences between raters. Most of the variation (87%) was due to differences between students. Approximately 12% of the residual variation was due to the interaction between students and raters. The relative and absolute generalizability coefficients, which provided information about relative or comparative decisions and criterion-referenced interpretation, respectively, were similar and high (0.95). A decision study varying the number of raters indicated that the relative and absolute decisions were virtually the same, with both indicating an acceptable level of reliability with just one rater’s observations. This suggests that the undergraduate raters who scored the student work were fairly consistent with each other. In other words, the undergraduates agreed in how to score the student work. There was little disagreement in terms of how to score the student work.

Interpreting Student Work

All of the middle school students completed a table that asked them to measure and record the current generated by the solar cell under the six conditions. The students then answered leading questions regarding the condition that generated the most current and whether the amount of current increased, decreased, or stayed the same when the solar cell was heated or cooled (see Appendix). However, when middle school students were asked to support their conclusions about the relationship between the amount of current generated and the temperature, only 11% used the information that they just gathered to provide an accurate statement. Forty six percent of the students provided vague responses, such as, “the light is what gave the cell its electricity” or “the current didn’t change at all with any of the other objects.” Some students (18%) also provided incorrect explanations, such as, “different temperatures make the power generate different.” The remaining 25% did not provide any detailed response but referred to the table on the front page (“the chart on the front”). Without further elaboration, it was difficult for the undergraduates to determine whether the middle school students actually understood the relationship between the amount of current generated and the temperature conditions.

The undergraduates were surprised by the low percentage of students who correctly used the information to provide accurate statements about the relationship between the amount of current generated and the temperature condition. Prior to the scoring of student work, the undergraduates were pleased with the implementation of the solar cell lessons because they completed their lesson plans and all of the middle school students completed the student worksheets. The undergraduates presumed that all of the middle school students could use evidence from the experiments to support their answers about the amount of current generated being dependent on the temperature of the solar cell. However, with this more systematic approach to looking at student work, the undergraduates realized that while the middle school students appeared to be paying attention and following along during the small-group lessons, many of the students could
not individually describe the relationship between the amount of current generated and different temperature conditions. The undergraduates were particularly surprised to identify several discrepancies for the students who were the most vocal during the small-group lessons and the written responses provided. This indicated to the undergraduates that the middle school students’ understanding was less solid than they originally thought.

This opportunity to reflect on student work led to further discussions about ways to implement the lessons that would gather additional information about individual student understanding during the course of the lesson rather than waiting until the end of the lesson. This also led to discussions about the benefits and challenges of implementing small-group activities. For example, the undergraduate engineering student expressed concerns about the amount of time available for each lesson. He was particularly concerned with being able to question individual students about related topics, such as the time of day the sun shines the brightest and how this might impact the amount of energy produced. The undergraduate engineering student suggested spending more time per group in an after-school setting. This would allow for more discussion as well as clarifications of misconceptions. The other undergraduates agreed with his suggestion but also pointed out that the students have other activities and not all of them would be able to attend after-school sessions. All undergraduates also indicated difficulty in paying attention to all students. Often times middle school students spoke at the same time or interrupted each other. The undergraduates indicated having a difficult time attending to multiple students. Their expressed concerns led to other strategies that might be utilized to assess individual student thinking for larger numbers of students such as providing activities that would teach students how to work collaboratively and provide opportunities for students to practice listening and responding to each other.

**DISCUSSION**

This paper describes how reflection about student work can be incorporated into a service-learning project. This is particularly useful for K-12 service-learning collaborations because student work is something that is typically produced but not always systematically collected and analyzed. The process of analyzing student work was particularly useful for two of the three undergraduates who went on to pursue secondary mathematics and science teaching credential degrees. Through this reflection, these undergraduates had the opportunity to connect their efforts to student outcomes and reflect on how to better structure learning opportunities to help all students gain understanding of solar energy. They are now working to implement these ideas in their own instructional practices as student teachers. The other undergraduate is not planning to pursue a teaching career but “enjoyed learning about solar cells” and “enjoyed getting to know whether or not I can teach to a group of people and how I could be prepared in the future (for teaching others).” Successful implementation of service-learning opportunities in engineering education requires innovative ways to incorporate reflection. This paper provides one example of how this reflection can be incorporated into K-12 outreach efforts and in doing so, help undergraduates and middle school students acquire the knowledge and skills needed to participate in STEM fields.
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REFERENCES


28Authors, “Identifying a solar cell misconception held by middle school students,” Paper presented at the ASQ Advancing the STEM Agenda in Education, the Workplace and Society conference, Menomonie, WI, 2011.


Appendix

Measure and record the current generated by the solar cell under the following conditions:

<table>
<thead>
<tr>
<th>Temperature Condition</th>
<th>Flashlight ON</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard (room temperature)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hair dryer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Warmer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Pack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Pack</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Under which condition was the most current generated?
Did the current increase, decrease, or stay the same when the solar cell was heated?
Did the current increase, decrease, or stay the same when the solar cell was cooled?
Does the current generated by the solar cell depend on the temperature of the solar cell?
What evidence do you have to support your answer?