The Impact of Socioscientific Issues-based Instruction on College Students' Knowledge Acquisition

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Abstract

The need for STEM literacy among undergraduates has fueled the exploration of innovative teaching methods in the higher education setting. Socioscientific issues (SSI)-based instruction is an instructional model that has yielded positive results in a variety of settings, including agricultural education. However, the multiple variables contributing to the impact of classroom instruction on student outcomes merits further investigation into the effectiveness of SSI-based instruction at the undergraduate level. This quasi-experimental study examined the impact of SSI-based instruction on undergraduate students' knowledge of solar energy. Nonequivalent groups were randomly assigned to either an SSI-based instructional module or a traditional instructional module. Results indicated that while both groups experienced significant gains in their knowledge of solar energy, SSI-based instruction was not more impactful than traditional instruction. Findings suggest that instructors looking to invigorate their classroom through innovative teaching methods explore the use of SSI-based instruction, as their students' learning should not be negatively impacted. Recommendations are made for researchers in order to better understand the impact SSI-based instruction has at the undergraduate level.

Keywords: socioscientific issues, instruction, solar energy, college students

Introduction

The need for U.S. citizens to be literate in science, technology, engineering, and mathematics (STEM) is undisputed (Zollman, 2012) – STEM skills and competencies "are integral and essential parts of daily life for virtually everyone in the United States and around the globe" (National Research Council, 1999, p. 1). Voting issues can be organized into 43 distinct categories, over half of which are tied to at least one aspect of STEM, according to data collected by Project Vote Smart (2014). STEM literacy also impacts business practices; public concern for environmental protection, animal welfare, and food safety have for years been important in establishing best practices in the agricultural, food, and natural resource sectors (Dimitri, Effland, & Conklin, 2005). The need for STEM literacy is founded in reports recommending efforts to "resolve (1) societal needs for new technological and scientific advances; (2) economic needs for national security; and (3) personal needs to become a fulfilled, productive, knowledgeable citizen" (Zollman, 2012 p. 12). Leaders in education acknowledge the value of STEM-literacy through standards, reports, and funding opportunities, yet efforts to improve STEM education have fallen short, as indicated by the focus of STEM literacy in the Next Generation Science Standards, the common core standards initiative, and the goals of the National Science Foundation's Improving Undergraduate STEM Education program (National Governors Association Center for Best Practices, 2010; Next Generation Science Standards Lead States, 2013). While national focus has been given to improving science education at the K-12 level, the "responsibility for sustaining excellence in science in the United States falls on research universities" (Howard Hughes Medical Institute, 2013, p. 3). Universities have responded to continued calls for increased quality in STEM education through establishing innovative centers and projects (Iglinski, 2012), employing alternative approaches to recruiting and retaining students to STEM majors, and experimenting with novel teaching approaches (President's Council of Advisors on Science and Technology, 2012).

Socioscientific issues (SSI)-based instruction is a STEM-focused teaching method that guides student learning in the context of complex societal issues. SSIs are multi-faceted, present in society, and controversial in nature (Chang-Rundgren & Rundgren, 2010). The vast majority of SSIs are rooted in agriculture, providing the industry with opportunities to teach agricultural concepts and literacy to students outside of school-based agricultural education. Faculty members within departments of Agricultural Education and related fields frequently focus on informal and nonformal methods of agricultural education, agricultural communications, and agricultural leadership, each of which is an appropriate context for learning about SSIs. Examples of SSIs include genetics and genetic engineering (Dori, Tal, & Tsauschu, 2003; Jimenez-Aleixandre, et al., 2000; Tal, Kali, Magid, & Madhok, 2011; Sadler & Zeidler, 2003; Zohar & Nemet, 2002), public health threats (Eastwood, Schlegel, & Cook, 2011; Kolsto, 2001; Tal & Hochberg, 2003; Wong, Hodson, Kwan, & Yung, 2008), animal welfare (Osborne, Eduran, & Simon, 2004), and environmental and energy issues (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007; Dori & Herscovitz, 1999; Eastwood, et al., 2011; Klosterman & Sadler, 2011; Roth & Lee, 2004; Sadler, Klosterman, & Topcu, 2011). Through a framework of learning experiences, students engaged in SSI-based instruction learn about the complex perspectives surrounding a specific SSI, as well as how to make decisions regarding that SSI (Sadler, 2011). Because students gain an understanding of multiple STEM-related fields and must make decisions based on that understanding, SSI-based instruction is an ideal method to develop a STEM literate populace.

Current research has examined the impact of SSI-based instruction on undergraduate students within the specific disciplines of science (Sadler & Zeidler, 2004), education (Sadler & Zeidler, 2003), biotechnology (Halverson, Siegel, & Freyermuth, 2009), biology (Sadler, 2004), psychology (Sadler, 2004), teacher education (Topcu, Sadler, & Yilmaz-Tuzun, 2010), and agriculture (Shoulders & Myers, 2013). While a few researchers have branched out to examine attitudes and gather information regarding SSIs from multi-disciplinary groups of students, little research has been conducted to examine the impact an SSI-based intervention would have on multi-disciplinary groups of students at the undergraduate level (Chang & Chiu, 2008; Fowler & Ziedler, 2010). The need for agricultural literacy among the nation's general public suggests that investigating appropriate methods for teaching multidisciplinary groups of students may be required in order to promote educated agricultural views among students in other fields.

Theoretical Framework

This study sought to examine the impact of an SSI-based intervention on undergraduate students' knowledge acquisition following Dunkin and Biddle's (1974) model of the theory of classroom teaching (see Figure 1).

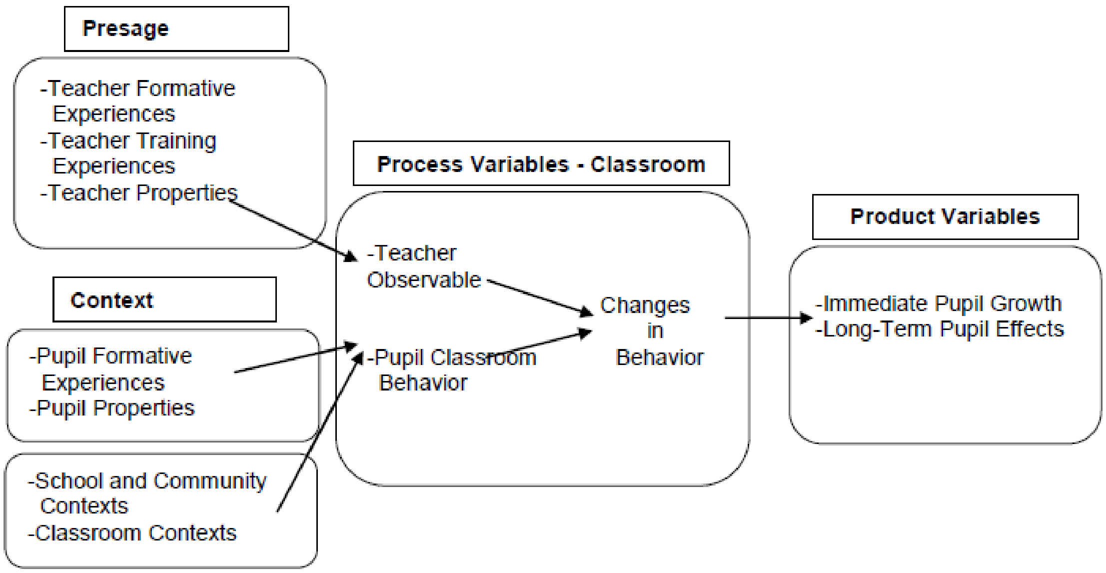

Figure 1. Model of the theory of classroom teaching (Dunkin & Biddle, 1974)

Dunkin and Biddle posited that a combination of presage, context, and process variables lead to impacts on product variables. Presage variables include teacher formative experiences, teacher training experiences, and teacher properties, each which contribute to the teacher's contributions to the classroom environment in which students engage. Context variables include pupil formative experiences, pupil properties, school and community contexts, and classroom contexts, which make up the components of the classroom environment unalterable by the teacher. The presage and context variables meet in the physical setting of the classroom, where process variables, including teacher and pupil behaviors, interact with one another to impact the reacting behaviors of each. These behaviors impact teachers' and students' perceptions, personal and professional growth, knowledge, and long term personal and professional actions. This study modified the classroom context of teaching methods to determine the impact of SSI-based instruction on the product variable of knowledge acquisition.

SSI-based instruction improves student learning experiences by allowing them to practice using scientific principles and concepts in situations similar to those they will experience in the future as citizens in a scientific society (Sadler, 2011). Because SSIs involve multiple facets of learning, including scientific principles and processes, consideration of morals and ethics, and political venues (Sadler, 2011), the mere insertion of relevant issues into existing educational practices does not provide students a substantial opportunity for developing scientific literacy. Eilks (2010) offered a five-step model for the operationalization of SSI-based instruction (as cited in Sadler [2011]):

1. Problem analysis. In this step, students are presented with an issue of interest through media reports or other strategies that highlight the reality and relevance of the issue.
2. Clarification of the science. Teachers help students understand the basic science underlying the issue.

3. Refocus on the socioscientific issue dilemma. Students refocus their attention on the issue and the associated social problems or controversies.
4. Role-playing task. Students assume roles for engaging in the negotiation of SSI. These roles may include parties to the issue debate or creators of media related to the issue.
5. Meta-reflective activity. Students are encouraged to reflect on their overall experiences with the issue and the underlying science. (p. 359)

While Eilk's model is helpful in designing one type of SSI-based instruction, Sadler (2011) posited the model to be "too prescriptive" to be applied to a variety of educational contexts, and proposed a framework that highlights considerations when designing SSI-based instruction rather than a step-by-step approach. This framework for SSI-based education includes four elements: classroom environment and teacher attributes, which impact the learning experience, and design elements and learner experiences, which make up the learning experience.

Design elements include the components instructors must consider when creating units of instruction based on an SSI. Essential design elements involve selection of an appropriate SSI and the early incorporation of that SSI into instruction. Also considered essential design elements are scaffolding to develop higher-order thinking skills, such as argumentation and decision-making, as these are not expected to be developed without overt and deliberate practice, and the inclusion of a culminating experience, designed to allow learners to come full circle in the experiential learning cycle by tying concepts and reflections back to the original SSI. Sadler (2011) recommended the use of media to increase student interest in the SSI and to tie the SSI to the students' world outside of school, as well as the use of technology as an ever-current learning tool due to the rapidly changing nature of SSIs.

Learner experiences include the actions and experiences in which students engage during the instruction. Sadler stated essential experiences should allow learners to engage in higher-order thinking skills, address the scientific concepts and theories related to the SSI, test ideas by collecting and analyzing data, and negotiate the social dimensions of the issue. Sadler also recommended that learner experiences consider both ethical dimensions and nature of science themes related to the SSI, as these aspects enhance student learning, but are not completely necessary in SSI-based instruction.

Classroom environment includes factors that aid in the successful implementation of an SSI within the culture of a given classroom. Essential features include established high expectations and norms for student participation, a collaborative and interactive culture, a demonstration of respect between teachers and students, and a safe environment in which differing perspectives can be expressed. These factors of classroom environment are crucial to the enrichment of student learning experiences because of the controversial nature of SSIs and the level of collaboration and discussion required in order to develop higher-order thinking skills (Sadler 2011).

Teacher attributes also impact successful implementation of SSIs into enriched student learning; Sadler (2011) specified four essential teacher attributes necessary when incorporating SSI-based instruction. These require that teachers are familiar with both the science content and social considerations of the SSI and surrounding issues, as they should help students connect the issue with the science surrounding it. Teachers should also hold a realistic view about limitations of their own and society's knowledge regarding the SSI, as the evolving nature of SSIs has implied that even the science community does not know everything about the issue. Teachers ought to be willing to accept uncertainties in the classroom, as the controversial nature of SSIs leads students to discuss alternative opinions, resulting in multiple potential acceptable decisions.

Conceptual Framework

The impact of SSI-based instruction on various student learning outcomes, based on grade level, assessment method, subject, and student ability, has been examined over the past decade. Yager, Yim, and Yager (2006) compared middle school students' academic gains between classes taught through an SSI-based approach and through a traditional approach. Ten weekly quizzes were utilized as a pre- post-test to measure middle school students' differences in concept mastery over the course of a semester. General science achievement was measured through the use of a common science semester exam, which was again administered as both a pre- and post-test to each group. Statistically significant gains were found for students in both groups with both measures. However, the gains between the two groups were not statistically significant, implying that the students taught through the SSI-based approach mastered science concepts at a level equal to that of students learning through traditional methods. Additionally, because the authors classified their study as action research, no attempt was made to validate the instruments or measure the reliability of their scores. While these findings suggest SSI-based instruction may not be any more impactful on student learning than traditional methods of instruction, the validity of the instrument brings a level of uncertainty to the results. Further, the study's focus on middle school education may not allow generalizability to undergraduate students, where excellence in science teaching is expected (Howard Hughes Medical Institute, 2013).

High school students are more akin to undergraduates than middle school students, though still separated in maturity and cognitive ability by four to five years. Zohar and Nemet (2002) conducted a study designed to explore the effects of a genetics-based SSI unit on ninth grade Israeli students' biological knowledge. Through the use of experimental and comparison groups, the authors compared biological knowledge gains between the two groups as evidenced by pretest and posttest questionnaires. While the experimental group learned about advanced genetics concepts through the Genetic Revolution unit, those in the comparison group learned the same genetics concepts through a booklet that presented information in a traditional textbook approach. The pretest and posttest consisted of an item designed to "[address] the extent to which students consider biological knowledge while thinking about the dilemma" (p. 43) and a 20-item multiple choice genetics knowledge test. With regard to consideration of biological knowledge, the authors found that students in the comparison group did not consider biological knowledge when considering the dilemma as frequently as those in the experimental group. This trend was continued with respect to the use of false considerations, as those were found more frequently in the comparison group responses. Alternatively, students in the experimental group correctly considered specific biological knowledge more frequently than those in the comparison group. With regard to biological knowledge gains, results indicated that students experiencing the SSI-based Genetic Revolution unit scored significantly higher than those in the comparison group.

Sadler, et al. (2011) sought to determine the impact of SSI-based instruction on student scientific content knowledge in two high school classes of average-achieving students. The authors posed problems associated with assessments directly aligned with interventions, which are not ideal for use as summative assessments due to their lack of assessment of knowledge transfer, and those that are broader in scope, which are insensitive to small changes resulting from a short-term intervention. To address these issues with types of assessments, this study utilized two different assessments based on their distance from the intervention in order to assess the unit's impact on students' scientific content knowledge. Proximal data were collected through the use of a test with items that related directly to the unit, while distal data were collected through the use of items from state and national exams. The proximal assessment included five open-ended questions relating to climate change, which was the SSI focus, and was analyzed using the constant comparative method. The distal test measured student knowledge in climate and temperature, greenhouse effects and climate change, chemical principles and processes, and graphical creation and analysis. Comparing results for pre and posttests, the authors found that there was a significant increase between the pretest and posttest responses for the first three items of the proximal assessment, indicating that the SSI-based instruction significantly improved students' proximal responses. Distal measures resulted in a significant increase in students' correct responses from the pretest to the posttest, with a medium effect size, implying that the SSI-based instructional unit not only helped students learn scientific content in the SSI context, but also transfer the content to other scientific contexts.

Klosterman and Sadler (2011) also incorporated both proximal and distal level measures into their study of the impact of a three-week global warming unit on eleventh- and twelfth-grade students' science content knowledge gains. As in the study by Barab, et al. (2007), the authors developed a distal-level measure assessing specific science standards from a pool of publicly released standardized test items. The proximal-level measure contained five open-ended questions regarding the specific curriculum of focus in the global warming instrument. Proximal-level response analysis indicated a statistically significant difference between pre-and post-assessments on three of the five questions; the final two questions were not analyzed due to the low frequencies in each scoring level. Contrary to the results in the 2007 study, Klosterman and Sadler (2011) found a statistically significant gain with a medium level effect size in students' distal-level scores. However, no comparison was done with alternative treatments to determine the treatment's effect as compared to traditional instruction.

Tal, et al. (2011) examined Israeli student scientific and genetics knowledge after exposure to the two-week WISE Simple Inheritance module. The science-knowledge integration test combined an original WISE knowledge-integration assessment with a revised version of the test that focused specifically on students' integrated understandings of the principles of simple inheritance, and lastly, contained a complex question related to how large family exterminations during the Holocaust has influenced simple inheritance, as this situation is relevant to Israeli families. Students were given the test after they were exposed to the module and one of two "enhancements," which were online interaction with a cystic fibrosis patient and a field trip to a hospital. The authors examined student responses to find evidence of differences in knowledge acquisition between the two groups, and found no significant differences. Because no pretest was administered, the authors could not determine the impact of the overall module on student knowledge acquisition.

In agricultural education, Shoulders and Myers (2013) sought to determine the impact of SSI-based instruction on secondary education agriculture students through the issue of lab-grown meat. Findings indicated that students' knowledge regarding animal science increased as a result of the SSI-based instruction. However, knowledge gains were influenced by grade level, number of completed agricultural education classes, and FFA membership.

Studies have displayed the impact of SSI-based instruction on student learning of scientific content in grades 5-12, largely in single group, pretest-posttest designs. These studies suggest the potential for SSI-based instruction to yield gains in student learning at other grade levels, such as the undergraduate level, where students should expect to be exposed to excellent science teaching (Howard Hughes Medical Institute, 2013). In addition to the advanced maturity and cognitive ability of undergraduate students as compared to the younger subjects of previous studies, the course selection process of undergraduates may yield different results, as students select their own courses of study. This study sought to address how these variables within the undergraduate population may impact student learning during SSI-based instruction.

Purpose and Objectives

The purpose of this study was to determine the impact of an SSI-based instructional module on undergraduate students' knowledge acquisition when compared to a traditional instructional module. To achieve this purpose, the following objectives were created:

1. To determine the impact of an SSI-based instructional module on undergraduate students' knowledge of solar energy.
2. To determine the impact of a traditional instructional module on undergraduate students' knowledge of solar energy.
3. To determine whether a difference exists between the impact of an SSI-based instructional module and a traditional instructional module on undergraduate students' knowledge of solar energy.

The following hypotheses were developed in order to meet the aforementioned objectives:
H_O^1: The SSI-based instructional module does not have an impact on students' knowledge of solar energy.
H_O^2: The traditional instructional module does not have an impact on students' knowledge of solar energy.
H_O^3: There is no difference between the impact of the SSI-based instructional module and the traditional instructional module on students' knowledge of solar energy.

Methods

This study employed a quasi-experimental nonequivalent control group design to assess students' knowledge acquisition before and after an SSI-based instructional module or a traditional module. While the classes themselves were randomly assigned to treatments, students were not randomly assigned to classes, so the groups were assumed to be nonequivalent (Cook & Campbell, 1979). Both the control and treatment modules introduced students to solar energy and its uses.

Participants

Due to the renewable energy content focus, the population for this study was the undergraduate student body at the University of Arkansas enrolling in undergraduate courses identified by a panel of experts to have a focus on sustainability offered during the Fall 2013 semester (N = 258). This panel of experts consisted of three faculty and one graduate student, each of whom have expertise in sustainability and renewable energy education. Courses were selected from the list of courses offered as electives to students pursuing a Sustainability Minor. These courses contained both Sustainability Minor students and students pursuing a variety of majors without the Sustainability Minor. The list of courses was then reduced to those focusing on some aspect of renewable energy, leading to a total of eight courses, seven of which were offered during the Fall 2013 semester. Instructors of six classes agreed to participate, leading to a total accessible population of 248 students. Absences led to a sample size of 141. Based on the population size, a sample size of at least 154 was necessary to obtain generalizable results at the 5% precision level (Israel, 2009). Therefore, the precision level of the study was adjusted to 7%.

Classes were randomly selected to participate in either the treatment or control. A total of 82 students from three classes were exposed to the SSI-based instructional module, while a total of 59 students from three classes were exposed to the traditional instructional module.

Intervention

Both the treatment and control consisted of one 90-minute lesson plan. While a greater intervention duration would have been favorable, instructors were not willing to give up their classes for longer than one class period. Because SSI-based instruction can be utilized for any duration (Sadler, 2011), the 90-minute lesson was deemed acceptable. Each intervention aligned with a set of five objectives focusing on solar energy: a) students will define solar energy and identify benefits and drawbacks of solar energy; b) students will explain how solar energy is used to create electricity; c) students will compare and contrast different materials used in solar technologies; d) students will analyze different solar array configurations; and e) students will use mathematical calculations to correctly size solar arrays for specific settings and evaluate a system’s impact on electricity bills.

The treatment lesson plan followed an SSI-based instructional format. Students first were presented with the issue through a video displaying the need for alternative energy sources. They were then introduced to the University of Arkansas’ sustainability plan and its performance on ASHE STARS, which is a benchmarking system used by the university to measure its sustainability efforts. Students saw on this benchmarking system that the University of Arkansas is currently not pursuing renewable energy investments. Students were then presented with the task of determining whether solar arrays should be installed at the university, supporting their decision, and determining the array configuration which would be most feasible. The students were given a worksheet to guide them through this decision making process during the class period. The worksheet allowed students to evaluate information given to them during the class lecture in order to inform their decisions. After the informative lecture, which focused on delivering content related to the five objectives, the students were asked to discuss their decisions using their newly acquired information as support.

The control lesson plan followed a traditional instructional format. Students were first introduced to the topic through a video that displayed the global interest of solar energy without presenting a need to increase renewable energy use. Students were then shown a small array located at the University of Arkansas for educational purposes. During the lecture, they were asked to complete a worksheet. This worksheet enabled students to apply information they learned during the lecture without asking them to make any decisions regarding solar energy investments. The class concluded by discussing their worksheet answers; students recited correct answers, and incorrect answers were corrected through discussion.

To ensure fidelity of intervention, O'Donnell's (2008) five criteria, including adherence, duration, quality of delivery, participant responsiveness, and program differentiation were considered. Adherence and duration were ensured by consistency in the lesson deliverer and in the delivery. All lessons for both interventions were taught by the same researcher. Quality of delivery was ensured through the use of a second researcher, observed each class and confirmed that each action on the lesson plan was followed by the researcher delivering the lessons. Duration was ensured by the use of 90-minute lessons within the setting of 90-minute class sessions. Participant responsiveness was observed by the evaluating researcher, who monitored students' use of the worksheets and guided off-task students as needed. Program differentiation was ensured through the use of a panel of experts, who evaluated both of the lessons for face, content, and construct validity. The panel consisted of three faculty members with expertise in SSI-based instruction, sustainability, renewable energy, and education.

Instrumentation

Pretests and posttests were to assess students' knowledge. Six multiple choice items were developed to assess learning on each of the five objectives for a total of 30 items. These items were placed into two random orders to create equivalent forms of a pretest and posttest. A panel of four experts in solar energy education and assessment development established face and content validity of the tests, as well as confirmed alignment between the items, learning objectives, and lessons. The assessments were pilot tested with a group of 149 undergraduates from the University of Arkansas; calculations of internal consistency yielded scores of .81 and .90, which was deemed acceptable (George & Mallery, 2003).

Data Collection

In-tact classes were recruited via electronic communication to their instructors prior to the Fall 2013 academic year. Instructors were able to select the date of the experiment for their classes in order to increase instructors' likelihood to allow their classes to participate. Each intervention was held during the regularly scheduled class time and in the class' regularly scheduled location. Researchers were first introduced to the students as guest speakers sharing information about solar energy. The researchers then briefly explained the study and dispersed paper copies of the consent form and pretest. Students were given 20 minutes to complete the pretest on provided scantron forms. Following that 20 minutes, materials were collected, worksheets were distributed, and the 45-minute lesson began. At the conclusion of the lesson, students were given paper copies of the posttest. Students had 20 minutes to record their answers on the accompanying scantron form. Materials were collected as students finished their posttests.

Data Analysis

Data were analyzed using SPSS Version 20 computing software. Descriptive data are reported using means and standard deviations of pretest and posttest scores. Null hypotheses were tested using dependent samples *t*-tests to compare pretest scores to posttest scores from each group and analysis of covariance to compare differences in scores between the two groups (Field, 2009). Analysis of covariance used standardized raw change scores as a dependent variable and standardized pretest scores as the covariate in order to account for differences among groups (Kenny, 1975). Effect sizes were calculated using Cohen's *d* for those differences which were found to be significant. They were interpreted using Cohen's (1988) recommendations.

Findings

Objective one sought to determine the impact of an SSI-based instructional module on undergraduate students' knowledge of solar energy (Table 1). Students whose classes were randomly selected to receive the SSI-based instructional module ($n = 82$) displayed a mean pretest score of 16.59 ($SD = 3.46$) and a mean posttest score of 20.12 ($SD = 2.83$). This mean score increase of 3.54 was found to be statistically significant by use of a dependent samples *t*-test. Interpretation indicated the effect size was large; students' mean posttest score fell at the eighty-eighth percentile of their pretest scores (Cohen, 1988).

Objective two sought to determine the impact of a traditional instructional module on undergraduate students' knowledge of solar energy (Table 1). Students whose classes were randomly selected to experience the traditional instructional module ($n = 59$) displayed a mean pretest scores of 15.34 ($SD = 3.39$) and a mean posttest score of 19.63 ($SD = 2.82$). This mean score increase of 4.29 was found to be statistically significant by use of a dependent samples *t*-test. Interpretation indicated again the effect size was large; students' mean posttest score fell into the ninety-first percentile of their pretest scores (Cohen, 1988).

Table 1.

Mean Pretest and Posttest Scores and Their Significance of Both Interventions

Intervention	Pretest *M*	Pretest *SD*	Posttest *M*	Posttest *SD*	*t*	*p*	*d*
SSI-based Instructional Module	16.59	3.46	20.12	2.83	4.27	<.0005	1.12
Traditional Instructional Module	15.34	3.39	19.63	2.82	14.43	<.0005	1.37

Note. All tests had possible score ranges of 0 – 30.

Objective three sought to determine whether a difference exists in the impact of the SSI-based instructional module and the traditional instructional module on undergraduate students' knowledge of solar energy. An ANCOVA using standardized scores indicated no significant difference between the two groups' changes in scores after adjustment for pretest scores, $F(1, 138) = .023$, $p = .88$.

Conclusions

Both intervention groups displayed significant increases in their knowledge of solar energy from pretest to posttest, leading the researchers to reject the null hypotheses stating the SSI-based instructional module and traditional instructional module would have no impact on students' knowledge of solar energy. These findings conflict those found by Barab, et al. (2007), which can be attributed to the 2007 researchers' acknowledgement of a possible ceiling effect. The results of this study support those found by Klosterman and Sadler (2011) and Yager, et al. (2006), who found significant gains in high school students' and middle school students' content knowledge scores following an SSI-based instructional module, respectively. Effect sizes for both groups were large, indicating that both instructional modules were considerably influential on changes in students' knowledge of solar energy.

While both groups displayed gains in their solar energy, findings indicated that students engaging in the SSI-based instructional module did not learn more or less information than the students engaging in the traditional instructional module. Therefore, the null hypothesis that no difference exists between the impact of the SSI-based instructional module and the traditional instructional module on students' knowledge of solar energy was retained. These findings are similar to those reported by Yager, et al. (2006), who found that SSI-based instruction led to gains in student knowledge that were at a level equal to those of students learning through traditional methods.

Implications and Recommendations

The results of this study imply that as a process variable, SSI-based instruction can lead to significant student learning, similar in its impact to traditional instructional methods. Examination of students' mean scores indicate that while students from both groups learned, both groups also failed to produce a mean score higher than 68% on any of the tests. Neither Eilks (2010) nor Sadler (2011) make recommendations as to the duration of an SSI-based instructional module. Similarly, traditional instructional modules occur at a variety of durations, often dependent upon the depth and breadth of the topic and the course's timeline. Findings from this study suggest that one 90-minute class period may be sufficient to improve students' content knowledge scores, but not to a level deemed to be satisfactory. While constraints related to the use of classes under the control of other instructors limited the researchers' ability to extend the duration of these particular instructional modules, instructors are encouraged to manipulate the duration of SSI-based instructional modules as they see fit within the specifics of their own classrooms.

Because of the multiple variables left unexamined in the model of the theory of classroom teaching (Dunkin & Biddle, 1974), this study's findings lead more to recommendations for future research than it does to recommendations for practitioners. This study examined one product variable related to student content knowledge. As shown in previously conducted studies, SSI-based instruction has the potential to impact students' proximal and distal content knowledge, as well as other outcomes such as argumentation, reasoning, and views of the nature of science. While results of this research display that SSI-based instruction is no more impactful on student knowledge than traditional instruction, the examination of additional outcomes could uncover additional benefits of SSI-based instruction. Researchers are encouraged to replicate this study in order to evaluate SSI-based instruction's impact on additional outcomes related to undergraduate students.

Researchers controlled for presage variables in this study by utilizing the same researcher to deliver all instructional modules. Dunkin and Biddle (1974) have posited that instructors' formative experiences, training experiences, and personal properties influence their teaching, and thereby influence process variables' impact on student outcomes. Future studies should examine the impact specific process variables, such as instructors' perceptions toward a specific SSI, have on student outcomes.

While classes were randomly assigned to interventions, the context variable of students' knowledge of solar energy before the intervention could have impacted the results of this study. These students may have had previous knowledge regarding or interest in solar energy because of their pursuit of a Sustainability Minor. Additional context variables, such as students' experience with specific SSIs and educational interests, should be acknowledged, and possibly controlled for, in future studies. Finally, this study examined learning impacts as a result of one SSI. Because varied SSIs are so prevalent in society, researchers are encouraged to examine the impact selection of SSI has on student outcomes.

The results of this study indicate that SSI-based instruction can remain a viable method of increasing outcomes related to STEM literacy among undergraduate students. However, maintaining a single focus on student content knowledge gains would do a disservice to the mission of the higher education system; STEM literacy, similar to undergraduate education, seeks to improve student outcomes in a variety of social, affective, and cognitive areas. The multi-faceted goals of STEM literacy and undergraduate education require instructors and researchers to investigate the impact of SSI-based instruction on numerous areas of student growth as they seek to improve STEM education.

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