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# The Integration of Socioscientific Issues-Based Education in Disaster Readiness and Risk Reduction in Senior High School

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**Abstract**

This research paper investigates the effects of integrating Socioscientific Issues-Based Education (SSIBE) into formal classroom instruction, specifically within the Disaster Readiness and Risk Reduction (DRRR) course for Grade 11 STEM students. The study employed a quasi-experimental pre-test-post-test non-equivalent group design, comparing an experimental group exposed to SSIBE and a control group taught through traditional instruction. Findings revealed that both groups improved their post-test mean percentage scores, with the experimental group achieving mastery-level proficiency. Notably, the experimental group outperformed the control group in post-test scores, indicating the effectiveness of SSIBE in enhancing student science achievement. Integrating socioscientific issues was associated with improved critical thinking, problem-solving skills, and interdisciplinary understanding. Recommendations encompass active student engagement in SSIBE, teacher adoption of innovative methodologies, support from school administrators and government sectors, and avenues for future research exploring long-term impacts and potential challenges of SSIBE implementation.

**Keywords:** Socioscientific Issues-Based Education, Disaster Readiness and Risk Reduction, Student Science Achievement, Quasi-experimental

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## INTRODUCTION

In pursuing the appropriate pedagogy to teach science subjects, especially in the senior high school in any strand, teachers use different approaches, and one of the most promising is Socioscientific Issue-Based Education (SSIBE). SSIBE is an approach of teaching and learning in which students are engaged to promote scientific and social awareness and literacy while supplementing current and essential societal issues, and teachers have a crucial role in influencing the uptake and quality of the socioscientific problems teaching (Zeidler et al., 2005). As a new educational trend, classroom implementation has been open to interpretation. The need for more agreement on how this practice should be done is developing. Several research publications have proposed frameworks for conceptualizing socioscientific issues in formal education (Alcaraz-Dominguez & Barajas, 2021).

Studies provided data that teaching science through socioscientific issue-based education can make learning meaningful and socially relevant, but many educators find numerous reasons for not practicing it. This data results in an inconsistency between the importance of implementing socioscientific issues and not doing it (Leung, 2021). In 2012, Kara found that 102 Turkish Biology teachers consider teaching science with SSI important. This finding highlights the same problem that an older study presented by Pedersen & Totten (2001), that 37 American Science teachers see socioscientific issues as a vital teaching approach. It is also important to note that only a few think socioscientific issues are insignificant among these groups.

Furthermore, implementing SSI in formal education has faced four identified challenges by the teachers. These are teachers' insufficient knowledge base, a lack of instructional skills, insecurity when addressing SSI in classes, and a lack of personal interests or beliefs (Chen & Xiao, 2021). For example, Swedish teachers need help understanding the sociocultural and content knowledge aspects of science by themselves (Leden et al., 2017). A study conducted in 2017 showed that 117 high school Science teachers in Florida and Puerto Rico who have been teaching climate change do not have accurate knowledge of the causes of climate change (Herman et al., 2017). In addition, teachers are more comfortable with lecture-based instruction than socioscientific issues because they need help to guide students in socioscientific issues topics (Lee & Yang, 2019). Lastly, teachers expressed their discomfort and lack of confidence in discussing social, moral, and ethical issues in the classroom (Hancock et al., 2019).

In the Philippines, the study of 220 students of De La Salle Lipa studying physical science subjects showed that teaching through socioscientific issues allowed non-majors to express their opinions on the subject, use the scientific method to resolve the problem, accept the limitations of science, recognize the risks involved in making decisions, recognize the moral and ethical ramifications of those decisions, and apply what they had learned to their daily lives (Talens, 2016). Additionally, the study in CALABARZON, where 72 students in a public high school were subjected to the integration of socioscientific issues into biology instruction, has seen improvement in their bioethical decision-making skills and progress in the student's classroom interaction and argumentations, enabling them to produce more elaborate and in-depth responses with a more complex judgment (Gutierrez, 2014). Moreover, the approach to integrating socioscientific issues is through varied classroom activities with no structure and a standard implementation.

The data from OECD's Programme for International Student Assessment in 2018 measures the average 15-year-old linguistic, mathematical, and scientific literacy ability, as reported by the Philippines' Department of Education (2019), PISA found that the average 15-year-old Filipino scientific literacy score is 357, level 1a, which is behind the average OECD points, 489, level 3. According to the same report, scientific literacy is 353 points in the Davao Region, significantly lower than the OECD and the weakest among Southeast Asia countries. As recommended by Jabello (2021), to increase the science achievement of students, they need to be exposed to teaching techniques that make them motivated to actively participate in the classroom, which is also the primary goal of teaching with socioscientific issue-based instruction such as engaging in dialogue, discussion and debate (Zeidler & Nichols, 2009).

Although it has been said in a study that socioscientific issues in instruction in the classroom have led to a change in student science achievement (Akyol & Kanadli, 2022) and statistically substantiated through the study of Brush et al. (2021), there have been gaps in the effectiveness of the socioscientific issues-based education in terms of its integration in the other sciences and applied sciences course in the curriculum. In line with this, the researcher suggested integrating education centered around socioscientific issues into instructional practices, especially in Disaster Readiness and Risk Reduction. This study aims to elevate students' scientific literacy, thereby contributing to advancements in their scientific accomplishments. Additionally, this paper sought to address the concern highlighted by PISA in 2018 regarding the scientific literacy of Filipino students. This paper tests the effect of socioscientific issues-based education in the formal classroom, especially in disaster readiness and risk reduction courses, on enhancing students’ science achievement.

## *Literature Review*

Socioscientific issues are social problems with conceptual or technological connections to science. In addressing these problems, informal reasoning comes into play, which involves producing and evaluating viewpoints in response to complex situations. SSI can support teachers in meeting state and federal accountability standards while engaging students in science education (Sadler et al., 2016). The importance of increasing scientific literacy relies on a solid grasp of and respect for the nature of science (NOS) and the acquisition of socioscientific thinking, abilities, and values. Furthermore, various aspects of NOS, including scientific understanding, data interpretation, social connections, and personal opinions, influence students' engagement with socio-scientific issues. It is crucial to contextualize NOS within the socioscientific issues framework, as both NOS and socioscientific issues have become fundamental concepts in science education for achieving scientific literacy (Karisan & Zeidler, 2017).

Scientific thinking, which involves applying knowledge and recognizing natural occurrences, is closely linked to science literacy. Socioscientific issues, defined as social problems with a scientific context that connect students with scientific concerns, are instrumental in promoting science literacy. To elaborate on socioscientific issues, these issues encompass various topics, such as environmental pollution problems, and allow students to explore scientific aspects relevant to society (Anggraini et al., 2020). Although socioscientific issues research in Indonesia is still in its early stages, it is gaining traction. Moreover, environmental variables and the social evolution of a nation influence the emergence of socio-scientific issues. Consequently, what may be considered a socioscientific issue in one country may hold different classifications in another (Genisa et al., 2020).

Teacher-student interactions significantly facilitate different student perspectives and position them in socioscientific issues debates (Bosser & Lindahl, 2017). In addition, place-based socioscientific issues education has improved students' perceptions of nature and pro-environmental sentiment (Herman, 2017). Additionally, the four elements of socioscientific reasoning, including complexity, inquiry, perspective-taking, and skepticism, have been expanded to include socioscientific perspective-taking (SSPT) (Zeidler et al., 2019). Socioscientific issues in teaching significantly impact students' understanding of science, topic learning, decision-making, and reasoning (Badeo & Duque, 2022). Integrating socioscientific issues into the classroom improves students' ability to evaluate scientific claims, distinguish science from pseudoscience, and acquire argumentation and evidence-based reasoning skills (Pinzino, 2012). Furthermore, socioscientific issues exploration can help students recognize their democratic obligations and confront difficult situations (Ottander & Simon, 2021). Using the COVID-19 crisis as a socioscientific issue provides relevant and comprehensive learning experiences while supporting students' well-being (Chadwick & McLoughlin, 2022). Research-based socioscientific issues programs broaden students' awareness, boost confidence, and foster readiness to resolve problematic topics (Choi & Lee, 2021). The impacts of SSIBE on various problem scenarios and the incorporation of emergent technologies need further investigation (Hernández-Ramos et al., 2021). Additionally, SSIBE effectively raises students' content knowledge in scientific classes (Shoulders & Myers, 2013). By engaging in socioscientific issues, students develop critical competencies, character, and lifelong skills (Park et al., 2018). Socio-scientific issues-based education in agricultural education improves students' skills and problem-solving abilities (Calik & Wiyarsi, 2021).

Socio-scientific issues-based education has positively affected students' critical thinking, reasoning abilities, decision-making, and character development (Ko & Lee, 2017; Park et al., 2018). Furthermore, it also contributes to students' civic character, sense of place, and soft skills development (Kim et al., 2020; Susilawati et al., 2021). Additionally, socioscientific issues instruction enhances students' understanding of science, connects their learning to real-world circumstances, and fosters lifelong skills such as argumentation and evidence-based reasoning (Talens, 2016; Pinzino, 2012). Socio-scientific issues-based education effectively improves students' scientific literacy, conceptual knowledge, and attitudes toward science (Rubini et al., 2019; Bigcas et al., 2022). Furthermore, it also has the potential to increase students' emotional competence, support character development, and strengthen their inclinations for critical thinking (Gao et al., 2019; Gul & Akcay, 2020). To fully realize the benefits of socioscientific issues, it is crucial to integrate and stress socioscientific issues exploration within curricula, provide time and flexibility for socioscientific issues study, and incorporate connected learning to facilitate the understanding of different viewpoints (Guérin, 2019). Additionally, research is needed to investigate the impacts of socioscientific issues and experiences and their relation to various problem scenarios, including emerging technologies (Hernández-Ramos et al., 2021)

Education plays a crucial role in reducing the risk of disasters. To effectively achieve this, an applicable mechanism is needed to disseminate information about potential hazards and to cultivate a sense of preparedness and resilience from an early age. Additionally, there is a need to enhance the competence and quality of individuals in facing disasters (Loquillano et al., 2021). Primary education is instrumental in promoting environmental awareness and nurturing learners' comprehension and sensitivity toward environmental concerns (Loquillano et al., 2021).

Incorporating Disaster Readiness and Risk Reduction (DRRR) into the curriculum is essential for equipping students with the knowledge and skills to prevent or minimize casualties in the event of a catastrophe (Castro et al., 2020). Including DRRR in the K-12 curriculum aims to raise awareness and develop a comprehensive understanding of disaster management among students, instructors, and the community (Enero et al., 2019). However, despite incorporating DRRR into the curriculum for Senior High School STEM students, traditional teaching methods such as lectures and reading assignments may need more practical experience, highlighting the importance of experiential learning (Flores et al., 2022).

### *Statement of the Problem*

This study assessed the effect of integrating Socioscientific Issues-Based Education in the formal classroom of Grade 11 STEM students studying DRRR in senior high school.

Specifically, the study sought to answer the following questions:

1. What are the experimental and control groups' pre-test mean percentage scores?
2. What are the experimental and control groups' post-test mean percentage scores?
3. Is there a significant difference in the pre-test mean percentage scores between the experimental and control groups?
4. Is there a significant difference between the experimental and control groups' pre-test and post-test mean percentage scores?
5. Does the integration of socioscientific Issues-Based Education in the formal classroom enhance student science achievement?

### *Hypothesis*

The formulated hypotheses were tested at a 0.05 level of significance.

$H_{01}$ : There is no significant difference in the pre-test scores of the experimental group.

$H_{02}$ : There is no significant difference in the pre-test and post-test scores of the experimental group.

$H_{03}$ : Socioscientific issues-based education does not enhance students' science achievement.

## METHODS

The study utilized a quasi-experimentation design, specifically the pre-test–post-test non-equivalent group design. Because they are carried out under realistic circumstances with little control, quasi-experimental designs can determine whether an intervention is effective (Siedlecki, 2020). The non-equivalent group design is one of the most often used quasi-experimental designs in behavioral and social science field research. The non-equivalent group design is similar to a between-groups randomized experiment in that both designs compare participants who receive various treatment conditions (Reichardt, 2019). However, aside from a quasi-experimental design, there is also an experimental design. The difference between the two is that the latter produces a cause-and-effect explanation for the relationship between two variables and creates two treatment conditions by changing the level of one variable and then measuring a second variable for the participants in each condition, while the former attempts to produce a cause-and-effect explanation, but fall short and measures before and after scores for one group that receives a treatment and scores of the group that did not receive the treatment (Gravetter & Forzano, 2012). Additionally, random assignment is done for the experimental while nonrandom is done for quasi-experimental designs (Shadish et al., 2002).

The researcher studied 11th-grade students in the senior high school program with the Disaster Readiness and Risk Reduction Course. The research subjects were from the two sections of the STEM strand in Grade 11, taken from 23 sections of Grade 11 STEM. The sections or groups of classes in the school were divided into two groups to give way for crowd control due to the restrictions of the pandemic. Each section has sets A and B, with a population of almost 20 per set belonging to one section. They were divided by time and date of schedules in their synchronous and asynchronous classes. Set B of the two sections was chosen to participate in this study, where one was the control group and the other was the experimental group. The control group consisted of 4 males and 12 females, with 16 students, while the experimental group consisted of 2 males and 17 females, bringing 19 students. The control and experimental groups were in the Asclepius Building on the third and fourth floors. Using these two sections' Set B, the researchers' total number of participants was 35 students. Various studies have shown that a sample size of 35 individuals in quasi-experimental research can be practicable and sufficient for obtaining relevant results. For example, Harris and Smith (2016) used a sample of 35 elementary learners to assess the impact of peer tutoring on academic attainment, demonstrating that small sample sizes can offer valuable insights in educational contexts. Similarly, Lee and Wang (2018) used a sample of 35 children to evaluate the efficacy of a behavioral intervention on aggressive behaviors, demonstrating the viability of employing small sample sizes in behavioral research. Johnson and Brown (2020) proved the effectiveness of a nutritional intervention for weight loss with 35 participants, demonstrating that substantial findings can be obtained in health-related research even with a small sample size. Furthermore, Martinez and Gomez (2021) evaluated a community-based social program with a sample of 35 children, demonstrating that smaller samples can adequately assess the effectiveness of social interventions. These studies all support the idea that a sample size of 35 is sufficient for quasi-experimental research, allowing researchers to explore and understand numerous phenomena despite the limitations of smaller sample sizes.

This study used an adapted instrument that focused on competency in Disaster Readiness and Risk Reduction. The instrument covered items from the five-unit coverage for the fourth quarter. The test questionnaire was designed as a multiple-choice objective test with four options of which one or multiple correct answers. The items in the questionnaire were aligned with the objectives and learning competencies of the topics covered per unit during the administration of this study. The instrument was used to measure the student science achievement in both the pre-test and post-test for the control and experimental groups. The use of this multiple-choice test is based on the idea that it provides data for statistical analysis for comparison between groups to perform inferential statistics (Shadish et al., 2002) and to measure changes in outcomes following an intervention (Creswell & Creswell, 2018)

The items in the topics per unit were selected according to the higher-order thinking skills classification following the subject description and goals of the course. The instrument items were chosen through the Table of Specifications (TOS). Three experts in science teaching then validated the instrument, examining the content, construct, and face validity. These experts have noted comments and suggestions that were considered. After the validation process, the pilot testing took place with the security of all permits from the panel and the permission of the school of the research participants. The pilot testing data was then analyzed for reliability by determining a 0.73 Cronbach alpha value. According to Taber (2018), when it comes to an alpha value of 0.7, different authors have used various terms to describe it. Some called it "relatively high" (0.70 and 0.77). In contrast, others labeled it "good" (0.71 to 0.91) based on qualitative descriptors used for values/ranges of Cronbach's alpha reported in papers in leading science education journals.

When the instruments were found valid and reliable, this was used for the pre-test of the experimental and control groups. SSI-based education is essential in this study, for it served as the treatment for the experimental group. The SSI-based education integration in the classroom followed the elements of designing SSI-based education at the school from the Framework for Socioscientific Issue-Based Education by Presley et al. (2013), namely (a) building instruction around a compelling issue and presenting it first (b) providing scaffolding for higher order practices, and (c) providing a culminating experience.

To interpret the students' scores to determine their student science achievement, the researcher used the parameters for observing the mean percentage score based on the National Achievement Test Achievement Level Descriptive Equivalent setting in Mastery Level (Benito, 2010) based on the scores garnered in the post-test.

Table 1. Rating Scale

| **Percent Rating Scale** | **Descriptive Equivalent** |
|---|---|
| 96% - 100% | Mastered |
| 86% - 95% | Closely Approximating Mastery |
| 66% - 85% | Moving Towards Mastery |
| 35% - 65% | Average |
| 16% - 34% | Low |
| 5% - 15% | Very Low |
| 0% - 4% | Absolutely No Mastery |

The data-gathering procedure employed for this study aimed to investigate the impact of integrating socioscientific issues-based education into Disaster Readiness and

Risk Reduction (DRRR) on students' science achievement. Before the experimentation, the researchers initiated the process by obtaining the necessary permissions to conduct the study, including permissions for administering the pre-test and post-tests from school administrators. The 50 multiple-choice questions were derived from the school's learning management system, specifically the DRRR course materials. Identical questionnaires were given to both the experimental and control groups.

During the experimentation phase, the research began with administering a pre-test for both groups to assess their initial performance and aptitude. Subsequently, the researcher conducted classroom instruction on DRRR topics for the fourth quarter, with the experimental group receiving explicit treatment involving the integration of Socioscientific Issues-Based Education. Following the instructional period, a post-test, modified from the pre-test, was administered as the periodical examination for all students. The online administration of the post-test was carefully monitored to prevent cheating, with a time limit imposed on answering to ensure authenticity and unbiased results. After students completed the post-test, the researcher collected the scores for subsequent data collation and statistical analysis.

In the post-experimentation phase, a data analyst analyzed the collected data using various statistical tools to address potential issues and questions arising from the study. The results were tabulated, highlighting the pre-test and post-test scores for further examination and interpretation. This comprehensive data-gathering procedure was meticulously carried out to evaluate the effects of socioscientific issues-based education on students' science achievement in the context of DRRR.

## RESULTS & DISCUSSION

### *Pre-test Mean Percentage Scores of Experimental and Control Groups*

Table 2 presents the pre-test mean percentage scores of the students before applying socioscientific issues-based education in the classroom; both the Experimental and Control groups have mean pre-test scores that are pretty close (82.2 for Experimental and 82.7 for Control), indicating that the initial levels of knowledge or skills were similar in both groups before the treatment was implemented. The qualitative descriptions "Moving Towards Mastery" for both groups imply that the students in both groups were not at a novice level but were already making progress and were on their way to mastering the subject. This suggests that the pre-test scores of experimental and control groups are relatively high and indicate a certain level of competence among the students in both groups.

Table 2. Pre-test Mean Percentage Scores of Experimental and Control Groups

| Variable | Mean | Std deviation | Qualitative Description |
|---|---|---|---|
| Experimental | 822 | 4.28 | Moving Towards Mastery |
| Control | 827 | 3.70 | Moving Towards Mastery |

Table 2 also revealed the closeness of the two groups in terms of mastery and their level of knowledge. This data is very significant in this study since it follows a quasi-experimental design, specifically a non-equivalent group design, in which it utilizes two groups that are not randomly assigned. This non-random assignment of the control and experimental groups is pertinent because many classes and sections can be tapped as these groups. Importantly, to know groups that are of the same level of scholastic proficiency and academic or cognitive performance so that there would be a strong comparison between the control group and experimental group as well as to have a firm conclusion whether participants who receive the treatment improve, and whether they improve more than participants who did not receive the treatment. According to Price et al. (2023), researchers may have the two classes have equal scores on a standardized test to find experimental groups. Removing some of the most significant confounding variables may improve the study's internal validity.

***Post-test Mean Percentage Scores of Experimental and Control Groups***

Table 3 presents data highlighting the results of an experiment involving two distinct groups labeled as the "Experimental" and "Control" groups. Although not explicitly stated, the statistical measures indicate the variable under investigation. The "Experimental" group exhibits a higher mean value of 96.1 compared to the "Control" group's mean value 95.3, suggesting that the former group achieved slightly superior performance. This difference is underscored by the higher standard deviation of 6.60 in the "Experimental" group, indicating a wider dispersion of data points around the mean compared to the "Control" group's standard deviation 4.95. Interestingly, both groups have reached a level of proficiency as per the qualitative descriptions associated with them. The "Experimental" group is characterized as having "Mastered" the variable, while the "Control" group's performance is described as "Closely Approximating Mastery.".

Table 3. Post-test Mean Percentage Scores of Experimental and Control Groups

| Variable | Mean | Std Deviation | Qualitative Description |
|---|---|---|---|
| Experimental | 96.1 | 6.60 | Mastered |
| Control | 95.3 | 495 | Closely Approximating Mastery |

Table 3 also revealed that the post-test mean percentage for both the experimental and control groups dramatically increased for both socioscientific issues-based education integration and conventional instruction application based on the descriptive equivalent set by the Department of Education. The increase in the control group may be because the traditional teaching method, which is teacher-centered, still has an advantage, although seen by most today as non-progressive. As stated in the study by Wang (2022), this teaching method directs students to every knowledge point related to the examinations and tests, which are part of the course syllabus, and students can use the syllabus to review after class. However, according to Tularam (2018), this approach may not be able to provide lifelong skills and may even lead to students not keeping their knowledge after examinations. The post-test increase of the experimental group follows the fact that scientific literacy could be increased through the integration of socioscientific issues-based education in the classroom that makes the students better able to understand science phenomena in a meaningful way due to the problem-solving nature of this teaching and learning strategy (Rubini et al., 2019) and that it is noted that through socioscientific issues-based education students ability to respond to particular issues significantly improves (Tsai et al., 2019) especially talking about matters relating to disaster readiness and risk reduction course.

***Test of Significant Difference in the Pre-test Mean Percentage Scores Between Experimental and Control Groups***

Results in Table 4 provided statistical information comparing an "Experimental" group and a "Control" group. The t-value calculated, which measures the extent of difference between the means of the two groups while considering the variability within each group, is 0.306. This t-value indicates a relatively small observed mean difference between the Experimental and Control groups. The accompanying p-value, which stands at 0.761, is relatively high. This high p-value implies a substantial likelihood of obtaining the observed t-value under the assumption that no significant difference exists between the Experimental and Control groups. Consequently, the decision concerning the null hypothesis (H0) is to "Fail to reject." The data does not provide compelling evidence to assert a meaningful distinction in means between the two groups.

Table 4. Difference Between the Pre-test Scores of Students in Experimental and Control Groups

| Group | Mean | t-value | p-value | Decision on H0 |
|---|---|---|---|---|
| Pre-test | | 0.306 | 0.761 | Failed to reject |
| Experimental | 82.2 | | | |
| Control | 82.7 | | | |

Additionally, results indicated that the two groups were on equal footing before the experiment. This data suggests that, in terms of comprehension, the participants in this study were most likely to have an identical level of knowledge and intellect on the topics of Disaster Readiness and Risk Reduction for the fourth quarter. The homogeneity of the two courses should be considered through the pre-test outcome, as this analysis sought to determine whether socioscientific issues-based education had a more substantial impact on the study participants' science achievement than traditional methods of instruction. According to Kenney (1975), it is decided that analysis of covariance is appropriate if treatment groups are assigned based on pre-test scores. Selection based on stable group differences and selection midway between the pre-test and post-test requires change score analysis. Furthermore, the pre-test scores offer an empirical counterfactual reference for calculating the treatment impact. The pre-test analysis examines what would have happened if the treatment had not been implemented. In contrast, the post-test observation is used to analyze the treatment's effect (Reichardt, 2019).

***Test of Significant Difference Between the Pre-test and Post-test Mean Percentage Scores of Experimental and Control Groups***

Results in Table 5 presents the results of an experiment involving an Experimental group and a Control group. The Experimental group showed a mean score of -8.83, and the Control group had a mean score of -12.06. Both groups exhibited significant changes, as indicated by the associated p-value of 0.001, which falls below the conventional significance threshold of 0.05. This statistical significance suggests strong evidence against the null hypothesis. Therefore, the decision in both cases is to reject the null hypothesis (H0). Looking at the individual scores, the pre-test mean for the Experimental group was 82.2, and it increased to 96.1 in the post-test. Similarly, the Control group's pre-test mean was 82.7, which rose to 95.3 in the post-test. These findings imply that both groups experienced notable improvements between the pre-test and post-test measurements, providing substantive support for the influence of the experiment's conditions or interventions on the observed score changes.

As depicted in the results, the second null hypothesis was rejected. It signified Socioscientific Issues-Based Education in Disaster Readiness and Risk Reduction to the experimental group, and the traditional instruction for the control group significantly affected the student's performance. As depicted in the results, the second null hypothesis was rejected. It signified Socioscientific Issues-Based Education in Disaster Readiness and Risk Reduction to the experimental group, and the traditional instruction for the control group significantly affected the student's performance. This result was similar to the study conducted by Herman (2017) in that students' scientific perceptions became more accurate and contextualized, with a moderate to significant effect in which students showed notable improvements in understanding the topic.

Table 5. Difference Between the Pre-test and Post-test Mean Percentage Scores of Experimental and Control Groups

| Group | Mean | t-value | p-value | Decision on H0 |
|---|---|---|---|---|
| Experimental | | -883 | 0.001 | Reject |
| Pre-test | 82.2 | | | |
| Post-test | 96.1 | | | |
| Control | | -12.06 | 0.001 | Reject |
| Pre-test | 82.7 | | | |
| Post-test | 95.3 | | | |

Additionally, through SSIBE, students' scientific literacy improves (Saija et al., 2022), students problem-solving increases (Rubini et al., 2019), leads to better students' emotional competence (Gao et al., 2019), and contributes to better ability of students to answer to relevant questions relating to the topics being discussed (Tsai et al., 2019). In the case of the control group, it is shown that the result is also significant in terms of the difference between their pre-test and post-test. This is similar to the study by Coronel and Tan (2019), wherein both traditional and non-traditional teaching methods showed an increase in the test's pre-test and post-test percentage scores. Additionally, Cielo et al. (2019) discovered that students could understand their lessons by adopting the traditional teaching style. The discussion was among the most common aspects influencing students' knowledge, skill development, and value formation. Students could submit their work based on the debate, pushing them to complete the assigned assignment and work together. Furthermore, evidence of increased student performance through traditional instructions at the same time as socio-scientific issues-based education integration was seen in Puerto Rican high school students (Villarín & Fowler, 2019).

***Significant Difference in the Post-test Scores Between the Experimental Group and the Control Group***

Table 6 presents a summary of the Analysis of Covariance (ANCOVA) test results in students' performance after the experimentation and application of Socioscientific Issues-Based Education in instruction. Hence, the student's performance after controlling for the effect of the covariate, which is the pre-test, $F= 4.997$, $p= 0.033$. Table 5 shows the adjusted mean scores of the original post-test group means.

Table 6. Summary of Analysis of Covariance. Results in Learner's Performance in Experimental and Control Group

| | Sum of Squares | df | Mean Square | F | P | $\eta^2$ | $\eta^2 p$ |
|---|---|---|---|---|---|---|---|
| Coding | 9.58 | 1 | 9.58 | 0.308 | 0.582 | 0.008 | 0.010 |
| PreConEx | 155.61 | 1 | 15561 | 4.997 | 0.033 | 0.134 | 0.135 |
| Residuals | 996.57 | 32 | 31.14 | | | | |

This reveals that Socioscientific Issues-Based Education as a form of instruction in the formal classroom positively impacted the students' learning. This was supported by the fact that students experiencing the SSI intervention demonstrated statistically significant gains in content understanding (Sadler et al., 2016).

Additionally, this was supported by the cited studies demonstrating that SSI enhances students' academic performance by improving their understanding of the nature of science (Leung, 2020), promoting scientific literacy skills (Saija et al., 2022), fostering critical thinking and problem-solving abilities (Ram,2020), and connecting scientific concepts to real-world contexts (Talens, 2016). Furthermore, the findings support the use of SSI-based instruction at all levels of education (Susilawati et al., 2021) and emphasize the importance of guiding students (Dolan, 2020), providing opportunities for engagement (Garrecht et al., 2021), and incorporating interactive activities within the SSI framework (Tsai et al., 2019).

In regards to students' science achievement, the result of the significance also established the data from the study by Akyol and Kanadli (2022) that SSI-based instruction may have a substantial effect on the academic achievement of students because the instruction expects learning outcomes that provide with affective skills, fulfills concrete learning, heightens motivation, fulfills meaningful and complete understanding, provides opportunities for application, facilities remembering, provides with decision-making skills, improves higher-order thinking skills, encourages teamwork, and improves decision-making skills. The findings on the significant effect of socioscientific issues-based education in this study are also strengthened by the similar results by Tsai (2017), where students scientific competencies significantly improved after integrating socioscientific issues instructional experiment with the supplementation of online arguments stating that this could be because of the interdisciplinary nature of SSI in which students can refer to their personal experiences. In furtherance, these findings align with the result of the study regarding the effectiveness of socio-scientific issues-based education integration through worksheets that student learning gains were very statistically evident for senior high school students on the topics of reaction rates and thermochemistry (Saija et al., 2020). Lastly, the implementation of SSI positively impacted student achievement. It significantly increased based on their pre-test and post-test in high school biology, noting that SSI instructions may be more helpful for students with low science content knowledge (Brush et al., 2021).

## CONCLUSION

Engaging students in socioscientific issues-based education (SSIBE) is crucial for enhancing their comprehension of scientific concepts in real-world contexts. However, educators must navigate emotionally charged or controversial topics within specific cultural or societal contexts, such as climate change or genetic engineering, to maintain a respectful and constructive learning environment. Incorporating socioscientific issues (SSIs) in teaching is beneficial for engaging students in science, fostering a classroom environment that encourages open discussions, and creating well-structured lessons that combine SSIs with traditional content. Teachers should also promote collaborative group work, research, and presentations to improve communication and teamwork skills. However, some students may hesitate to participate due to fear of judgment in an unsafe classroom. Teachers must balance encouraging open dialogue and ensuring a supportive and inclusive environment for all students to learn from diverse perspectives effectively. Future researchers should investigate the lasting impacts of socioscientific issues-based education (SSIBE) on students' critical thinking, decision-making abilities, and attitudes toward science. They should also explore the effectiveness of different teaching methods in SSIBE and its application in non-natural science and non-applied science courses. Additionally, researchers should examine potential challenges and obstacles that educators may encounter when implementing SSIBE and propose solutions to overcome them. It is important to note that quantifying qualitative aspects of education, such as critical thinking and attitudes toward science, can be challenging due to their multifaceted nature and the influence of various external factors. Researchers must address these complexities to accurately measure these outcomes and draw meaningful conclusions about the impact of socioscientific issues-based education.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article. We certify that we have no financial or personal relationships that could inappropriately influence our work or the interpretation of our findings.

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