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Contextualizing Organic Chemistry through Science–Technology–Society (STS) Pedagogy: Enhancing Conceptual Understanding and Reflective Thinking for Life Sciences Learners

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Abstract

The increasing demand for scientific literacy and contextualized science instruction has highlighted the need for innovative pedagogical approaches that promote meaningful learning in Organic Chemistry. This study investigated the effectiveness of **Science–Technology–Society (STS)-based Organic Chemistry instruction** in advancing students' conceptual understanding and reflective thinking within life sciences education. Specifically, it examined students' preconceptions regarding Organic Reactions prior to instruction and the changes in their conceptions following the implementation of an STS-based instructional module. The study employed an **action research design** guided by **W. Edwards Deming's Plan–Do–Study–Act (PDSA) Model**, implemented in two iterative cycles involving the design, validation, implementation, and evaluation of an STS-based learning module. Participants were **ten first-year Bachelor of Science in Fisheries and Aquaculture Sciences (BFAS) students** enrolled in Organic Chemistry at Isabela State University–Roxas Campus during the second semester of School Year 2018–2019. Data were collected using a researcher-developed 20-item Concept Test, the Students' Perceptions of Science Class Questionnaire, the Questionnaire to Measure the Level of Reflective Thinking, and the Attitudes toward the Use of STS-Based Activities Questionnaire. Descriptive statistics and the **Wilcoxon Signed-Rank Test** were employed to analyze students' conceptual understanding before and after the intervention. Findings revealed that students initially possessed limited conceptual understanding and several misconceptions concerning Organic Reactions. Following the implementation of the STS-based instructional module, students demonstrated substantial conceptual improvement, as evidenced by an increase in the mean concept test score from **8.60** to **12.90** and a statistically significant difference between pretest and posttest scores (**$Z = -2.818$, $p = .005$**). The intervention effectively facilitated conceptual change by enabling students to reconstruct prior knowledge through contextualized, inquiry-oriented, and learner-centered learning experiences. The findings suggest that integrating the **Science–Technology–Society (STS) instructional approach** into Organic Chemistry instruction significantly enhances conceptual understanding and reflective thinking while promoting scientific literacy among life sciences students. The study recommends the wider adoption of STS-based pedagogical approaches in higher education science curricula to foster meaningful learning and develop scientifically literate graduates capable of applying chemical concepts to real-world biological, environmental, and societal contexts.

Introduction

The goals of scientific and technological literacy called for in a reform of science teaching require that the educational objectives of our high-technology society call for innovative effort to improve our country's agrarian and industrialized periods. Literacy is not a skill that can be taught as such. It requires a social awareness and an understanding of how human reasoning and decision making are used in dealing with science-related social, personal, political, and economic, and ethical issues. (Hurd, 1986). Recent science education reform efforts have focused on science instruction that enhances student understanding of the nature of science, enables them to critically analyze scientific information as well as to apply it in real life situation, and sets them on a path of lifelong learning in science. (Dass, 2005). And the success of science education reform depends on the teachers' ability to integrate the philosophy and practices of current programs of science education with their existing philosophy (Mansour, 2009). Through Chemistry education, students are guided to develop their intellectual ability to think critically, be creative and innovative. Furthermore, it is hoped that the students will possess the culture of science and technology and able to create a caring, dynamic and progressive society. They will be responsible for environment and have admiration for the creator. Concurrently, application of knowledge and skills which are based on scientific attitudes and 8 values will enable students to make decisions and solve problems in life more effectively. As a result, they will be able to explore the treasures of nature, adapt to the environment, make innovative creations, and even manage to overcome problems and difficulties (Surif, 2012). An STS to science education aims to develop a student-centered orientation that animates students' cultural self-identities, their future contributions to society as citizens, and their interest in making personal utilitarian meaning of scientific and technological knowledge. (Aikenhead, 2005). It is an interdisciplinary field of study that seeks to explore and understand the many ways that modern science and technology shape modern culture, values, and institutions on the one hand, and on the other how modern values shape science and technology (Monsour, 2009). Science-Technology-Society (STS) is recognized as reform in science education across the world. It involves learners in experiences, questions, and issues which are related to their lives. Situations are sought which will engage the students. STS teachers try to create situations where students will need the basic concepts and process skills so many wishes to force on to their students "because they will need them in the future." STS empowers students with skills which allow them to become active, responsible citizens by responding to issues which impact their lives. Experience with science in the STS format creates the scientifically literate citizenry for the 21st century for which most learn (Yager , 1992).

Statement of the Problem

The action research is designed to explore the effectiveness of STS based activities in organic reactions on students' conceptual understanding, reflective thinking and attitudes towards its use. Specifically, to seek answer for the following questions:

1. What are the students' preconceptions on Organic Reactions prior to instruction?

2. What are changes in students' conceptions on organic reactions after instruction?

Methods

The study employed an **Action Research Design** utilizing **W. Edwards Deming's Plan–Do–Study–Act (PDSA) Model**, a systematic framework for continuous improvement that is widely used in educational research to enhance instructional practices through reflective inquiry and evidence-based decision-making. Action research enables teachers to identify classroom concerns, implement appropriate interventions, evaluate their effectiveness, and refine instructional practices based on the findings. Guided by the PDSA model, the research was implemented in two iterative cycles. The first cycle focused on the design, development, validation, and refinement of a learning module on Organic Reactions. During this phase, the instructional material was carefully developed, validated by subject experts, and revised to ensure its content validity, pedagogical appropriateness, and alignment with the intended learning competencies. The second cycle involved the implementation of the validated module among first-year Bachelor of Science in Fisheries and Aquaculture Sciences (BFAS) students enrolled in Organic Chemistry during the second semester of School Year 2018–2019 at Isabela State University–Roxas Campus. These students represented the first cohort of learners who completed the Philippine K–12 Basic Education Curriculum before entering higher education, making them an appropriate group for evaluating the effectiveness of instructional innovations intended to strengthen conceptual understanding in chemistry. The participants were purposively selected because they were officially enrolled in Organic Chemistry, the subject where the intervention was implemented. Their participation provided valuable insights into the effectiveness of the developed module in enhancing conceptual understanding, reflective thinking, classroom perceptions, and attitudes toward learning Organic Chemistry through STS-based instruction.

The study was conducted at **Isabela State University–Roxas Campus**, one of the constituent campuses of the Isabela State University System located in the Municipality of Roxas, Province of Isabela, Philippines. Established on June 10, 1978, through Presidential Decree No. 1434, the university was created through the integration of several state-supported educational institutions into a unified university system committed to providing quality instruction, research, extension, and production services. The Roxas Campus serves as the only government institution of higher learning in the western portion of Isabela, commonly referred to as the Mallig Plains. Initially operating in Barangay Matusalem, the campus expanded its facilities after a two-hectare property in Barangay Rang-ayan was donated in 1995. In 2000, the Roxas Memorial Agricultural and Industrial School was integrated into the Isabela State University System, further strengthening the campus's academic programs and institutional capabilities. At present, the campus occupies more than 1.3 million square meters distributed across three strategically located sites and has been recognized as the Provincial Center of Excellence in Fisheries. Several of its academic programs, including Fisheries, Agriculture, Agribusiness, Secondary Education, and Information Technology, have obtained Level II accreditation from the Accrediting Agency of Chartered Colleges and Universities in the Philippines (AACCUP). The researcher has been a faculty member of the university for almost sixteen years, providing familiarity with the instructional environment, curriculum implementation, and student characteristics, thereby facilitating the successful conduct of the study.

Several validated research instruments were utilized to collect quantitative data necessary for evaluating the effectiveness of the intervention. The primary instrument was a **20-item researcher-developed Concept Test** designed to measure students' conceptual understanding of Organic Reactions before and after the implementation of the instructional module. The test covered fundamental concepts such as electrophilic, nucleophilic, and radical reactions; addition, substitution, and elimination reactions; reaction mechanisms; solvent effects; nucleophilicity; reactivity order; selectivity; stability order; and reaction coordinate diagrams. The test items were constructed based on the cognitive domains of Bloom's Taxonomy, specifically assessing knowledge, comprehension, application, analysis, and evaluation. To assess students' perceptions of their classroom learning environment, the study adopted the **Students' Perceptions of Science Class Questionnaire** developed by Bernardo, Limjap, Prudente, and Roleda (2008). The instrument measured five dimensions of classroom instruction, namely learner-centered pedagogy, science inquiry activities, positive affect and attitudes, grades as feedback, and support for self-learning and effort. Minor revisions were introduced to align the instrument with the objectives of the study, and participants responded using a five-point Likert scale ranging from strongly disagree to strongly agree. Previous studies established the reliability of the instrument with a Cronbach's alpha coefficient of 0.935, indicating excellent internal consistency. The study also utilized the **Questionnaire to Measure the Level of Reflective Thinking** developed by Kember and Leung (2000), which assessed four dimensions of reflective thinking, namely habitual action, understanding, reflection, and critical reflection. The instrument was adopted without modification and administered using a five-point Likert scale to determine students' levels of reflective thinking before and after the intervention. Previous validation studies reported acceptable reliability coefficients, confirming its suitability for educational research. Finally, the **Attitudes toward the Use of Science–Technology–Society (STS)-Based Activities Questionnaire** was administered to examine students' motivation, engagement, perceived usefulness, classroom participation, and overall acceptance of the STS-based instructional approach. Collectively, these research instruments generated comprehensive data that enabled the researcher to determine the effectiveness of the developed instructional module in improving students' conceptual understanding, reflective thinking, classroom experiences, and attitudes toward learning Organic Chemistry.

Findings

Statement of the Problem 1

What are the students' preconceptions on Organic Reactions prior to instruction?

Figure 7. Item Analysis on Students' Preconceptions on Organic Reactions

(Adapted from the dissertation. The original presents the number of students who answered each of the 20 concept-test items correctly before instruction.)

Explanation

Figure 7 presents the item analysis of the **20-item concept test** administered before the implementation of the Science–Technology–Society (STS) Model of Teaching. The test measured students' prior knowledge on the fundamental concepts of Organic Reactions, including addition, substitution, and elimination reactions, as well as reaction mechanisms involving electrophilic, nucleophilic, and free-radical reactions. It also covered concepts such as reactivity order, solvent effects, selectivity, stability order, reaction coordinates, nucleophilicity trends, and the mechanisms of SN1, SN2, E1, and E2 reactions. The items were constructed to assess different cognitive domains based on Bloom's Taxonomy, ranging from knowledge to evaluation.

The results revealed that although several students correctly identified the basic types of organic reactions, only a few demonstrated adequate understanding of the underlying principles governing these reactions. Most participants encountered difficulty explaining reaction mechanisms, predicting reaction products, identifying solvent effects, determining reaction rates, and applying conceptual knowledge to unfamiliar situations. The low number of correct responses across many test items indicates that the students possessed limited conceptual understanding before formal instruction.

Interpretation

The findings indicate that the participants entered the Organic Chemistry course with **minimal background knowledge and several alternative conceptions** regarding Organic Reactions. Their prior understanding was largely limited to recalling the names of reactions rather than comprehending the scientific principles that explain how and why these reactions occur. These misconceptions have the potential to hinder subsequent learning if not properly addressed through appropriate instructional interventions. Consequently, the results emphasize the importance of implementing learner-centered and contextualized instructional strategies, such as the STS Model of Teaching, to facilitate conceptual change and promote meaningful learning.

Statement of the Problem 2

What are the changes in students' conceptions on Organic Reactions after instruction?

Table 1

Descriptive Statistics for Pre- and Post-Concept Tests in Organic Reactions

Test	N	Mean	Standard Deviation	Minimum	Maximum
Pre-test	10	8.60	2.32	5	11
Post-test	10	12.90	1.60	11	15

Table 9 presents the descriptive statistics of the participants' scores before and after the implementation of the STS Model of Teaching. Prior to instruction, the participants obtained a mean score of **8.60** out of 20, indicating limited conceptual understanding of Organic Reactions. After participating in the STS-based instructional activities, the mean score increased substantially to **12.90**, representing an improvement of **4.30 points**. Likewise, the standard deviation decreased from **2.32** during the pre-test to **1.60** during the post-test, suggesting that students' performances became more consistent following the intervention. The increase in the minimum score from **5** to **11**, together with the increase in the maximum score from **11** to **15**, further demonstrates that all participants benefited from the instructional strategy.

The descriptive statistics indicate a marked improvement in students' conceptual understanding following the implementation of the STS Model of Teaching. The increase in mean performance suggests that the intervention successfully addressed students' misconceptions and facilitated meaningful conceptual change. Moreover, the reduced variability in scores indicates that learning gains were experienced by the participants as a group rather than by only a few individuals.

Table 2

Wilcoxon Signed-Rank Test on Pre- and Post-Conceptions in Organic Reactions

Comparison	Z-value	p-value	Decision
Pre-test vs. Post-test	-2.818	.005	Significant

Level of significance: p < .05

To determine whether the observed improvement in students' conceptions was statistically significant, the Wilcoxon Signed-Rank Test was employed. As shown in Table 10, the analysis yielded a **Z-value of -2.818** with an associated **p-value of .005**, which is lower than the established significance level of **0.05**. This result indicates a statistically significant difference between the participants' pre-test and post-test scores after exposure to the STS-based instructional module.

The significant result demonstrates that the implementation of the Science–Technology–Society Model of Teaching effectively improved students' conceptual understanding of Organic Reactions. The intervention enabled learners to replace inaccurate prior conceptions with scientifically acceptable explanations through contextualized activities, collaborative learning, and authentic applications of chemistry concepts. The findings provide strong empirical evidence that the STS-based instructional approach promotes conceptual change and facilitates deeper understanding of complex Organic Chemistry topics. These results further support the use of innovative, learner-centered instructional strategies in improving science education and enhancing students' higher-order thinking skills.

Conclusion

The findings of the study demonstrate that students initially possessed **limited conceptual understanding and several misconceptions regarding Organic Reactions** before the implementation of the Science–Technology–Society (STS) Model of Teaching. Their preconceptions reflected insufficient prior knowledge of fundamental concepts such as reaction mechanisms, reactivity patterns, nucleophilic and electrophilic reactions, and the application of these concepts to authentic scientific situations. The low pretest performance indicated that many students relied on fragmented and superficial understandings, which constrained their ability to analyze and explain organic chemical processes accurately.

Following the implementation of the STS-based instructional module, a substantial improvement in students' conceptual understanding was observed. The significant increase in posttest scores, together with the statistically significant results of the Wilcoxon Signed-Rank Test, confirmed that the intervention effectively facilitated conceptual change among the participants. The STS instructional approach enabled students to reconstruct their prior knowledge, replace misconceptions with scientifically accurate explanations, and develop a deeper understanding of Organic Reactions by relating chemistry concepts to real-life contexts and societal issues. The findings therefore establish that contextualized, learner-centered, and inquiry-oriented instruction significantly enhances conceptual understanding and promotes meaningful learning in Organic Chemistry. Consequently, the STS Model of Teaching may be considered an effective pedagogical approach for improving students' conceptual mastery and fostering higher-order thinking skills in science education.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are offered:

1. **Science educators** are encouraged to integrate the **Science–Technology–Society (STS) Model of Teaching** into Organic Chemistry instruction to promote meaningful conceptual understanding. Contextualized learning activities that connect chemistry concepts with real-life situations should be consistently incorporated to help students replace misconceptions with scientifically accurate explanations and enhance higher-order thinking skills.

2. **Chemistry teachers** should conduct **diagnostic assessments** at the beginning of instruction to identify students' preconceptions and misconceptions regarding complex chemistry concepts. The results of these assessments may serve as a basis for designing appropriate instructional interventions that directly address learners' conceptual difficulties and facilitate conceptual change.

3. **Higher education institutions** should encourage the development and utilization of **innovative instructional modules and contextualized learning materials** grounded on the STS framework. These instructional resources should be aligned with course outcomes and designed to promote inquiry, critical thinking, reflective learning, and authentic problem-solving among students.

4. **Academic administrators and curriculum developers** may consider integrating STS-based pedagogical approaches into the chemistry curriculum and faculty development programs. Professional development activities, such as workshops, seminars, and Learning Action Cell (LAC) sessions, should be organized to strengthen teachers' competencies in designing and implementing learner-centered and contextualized science instruction.

5. **Future researchers** are encouraged to replicate the study using larger and more diverse populations from different higher education institutions and academic disciplines to establish the generalizability of the findings. Similar investigations may also employ experimental or mixed-methods research designs to compare the effectiveness of the STS Model of Teaching with other innovative instructional approaches in improving conceptual understanding, reflective thinking, scientific reasoning, and academic achievement.

6. Future studies may further investigate the **long-term retention of conceptual understanding** developed through STS-based instruction by conducting delayed posttests and longitudinal assessments. Such investigations would provide valuable evidence regarding the sustainability of conceptual change and the lasting impact of contextualized science instruction on student learning.

7. Researchers may likewise explore the influence of the STS Model of Teaching on other important learner outcomes, including **scientific literacy, problem-solving skills, decision-making abilities, collaborative learning, environmental awareness, and attitudes toward science**, to provide a more comprehensive evaluation of its educational effectiveness.

8. Finally, educational institutions should continue promoting **student-centered, inquiry-based, and context-oriented instructional practices** that encourage learners to actively construct knowledge, relate scientific concepts to societal issues, and develop the competencies necessary for lifelong learning and responsible citizenship. The successful implementation of the STS Model of Teaching demonstrated in this study provides empirical support for adopting innovative pedagogical approaches that enhance conceptual understanding and improve the overall quality of science education.

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