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SOCIOSCIENTIFIC ISSUE-BASED UNDERGRADUATE STUDENT WORKSHEETS ON SCIENTIFIC LITERACY AND ENVIRONMENTAL AWARENESS

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ABSTRACT

Scientific literacy and environmental awareness are skills needed in the 21st century. Therefore, education must provide these skills. This research aims to analyze the effect of SSI-based undergraduate student worksheets on chemical thermodynamics. Pre-experimental research with a pretest-posttest control group design was employed to compare SSI-based and science-based undergraduate student worksheets. Chemistry education students at FKIP Universitas Riau for the 2022/2023 academic year were selected as samples. The experimental and control groups were established based on the homogeneity of their previous academic scores. This study evaluated two outcome variables: scientific literacy ability and environmental awareness. The research instrument is a scientific literacy test using scientific literacy description questions and environmental awareness questionnaires. Scientific literacy test scores were analyzed using the Independent Sample T-test, and environmental awareness questionnaire results were analyzed using the Mann-Whitney U-Test. Increased scientific literacy and environmental awareness of students were analyzed using the N-gain test. The results showed that the experimental group's scientific literacy and environmental awareness were significantly higher than the control group. Therefore, it can be concluded that SSI-based undergraduate student worksheets effectively increase scientific literacy and environmental awareness.

Keywords: environmental awareness; scientific literacy; socioscientific issues

INTRODUCTION

The transformation of the 21st century as the Era of Human Capital is where science and technology develop rapidly, significantly impacting free competition in all aspects of human life (Pratiwi, 2019). As members of society, students must disrupt themselves as reflective, responsive, and adaptive individuals with a good understanding of science to apply the knowledge to solve real-life problems (Rahayu, 2017a). The statement is closely related to the ability to be literate in science. Scientific literacy is one of the skills needed in the 21st century, as identified by the World Economic Forum (Forum, 2015).

The ability to detect issues, learn new knowledge, interpret scientific phenomena, and make decisions based on data and features of science and technology is known as scientific literacy (OECD, 2016). Internationally, the purpose of developing scientific literacy is for students to have the ability to understand and participate in debates about science and technology. The intention of scientific literacy is to increase students' skills to think critically, apply science ideas in meaningful ways, and make appropriate, well-rounded decisions about issues that arise in daily life (Rahayu, 2017b).

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Science learning, including chemistry, not only emphasizes understanding concepts, but students are required to apply science concepts to solve problems related to chemistry in everyday life. Assessing students' scientific literacy in chemistry education, however, has not been the subject of much research. Based on the results of the 2018 PISA (Programme for International Students Assessment), Indonesian students' scientific literacy ranks 72nd out of 78 participating nations (Schleicher, 2019). Meanwhile, based on several previous research results, scientific literacy skills, especially in chemistry education students, are in the low category (Rahmayanti et al., 2021; Sumanik et al., 2021). Therefore, scientific literacy is needed by chemistry education students today.

There are a number of innovative approaches that can be used to encourage students to read, think, investigate, and make decisions about specific topics in order to enhance scientific literacy (Widodo et al., 2020). This effort can be conducted by providing issues related to daily life (Dewi et al., 2019; Widodo et al., 2020; Rohmah et al., 2022), such as socioscientific issues (SSI). SSI was chosen as a learning context because it can improve scientific literacy (Sadler, 2011; Zeidler, 2014).

Socioscientific issues discuss dilemmas that society faces and relate to a conceptual, procedural, or technological context in science (Ke et al., 2021). Applying socioscientific issues in learning guides students to think based on scientific evidence and integrate components from various aspects of life, including scientific, social, ethical, and moral aspects (Siribunnam et al., 2014; Zeidler et al., 2019). This socioscientific issue-based learning benefits students by helping them achieve decision-making (Eggert et al., 2016; Kinskey & Zeidler, 2021). Decision-making is essential in developing students' scientific literacy and producing solutions to daily problems (Saija et al., 2022).

One of the topics in SSI, environmental issues, is used as the learning context (Kinslow et al., 2018). Environmental issues are directly related to environmental problems, such as climate change, pollution, and preservation (Zeidler & Kahn, 2014). This environmental issue is closely related to individual awareness of the environment. According to Tan et al. (2014) and Chen (2020), it is crucial to understand students' environmental awareness well and nurture students to strengthen the knowledge, attitudes, and skills required to overcome environmental problems.

The 2018 PISA analysis by the OECD (2019) shows that students' awareness of environmental issues is directly proportional to their level of knowledge and scientific literacy skills. This result proves that students' awareness of environmental issues is still low. Erna et al. (2023) stated that only a few programs exist in Indonesian universities to develop students' responsibility for the environment. As a result, academic institutions need to offer a platform for raising environmental awareness using a range of instructional initiatives.

Based on preliminary research on chemistry lecturers of two universities in Riau, they have never made advantage of SSI-based learning. Additionally, according to the interview data, undergraduate students were never given SSI-based worksheets as teaching materials during the learning process. Using contextual learning resources as media can increase literacy, sensitivity, and action to overcome environmental problems (Suryawati et al., 2020).

One of the most needed learning resources is SSI-based undergraduate student worksheets based on contextual and authentic environmental issues. In the 21st century, technology is vital in helping implement learning. Electronic-based teaching materials are one technology to support learning (Noer et al., 2020). Therefore, SSI-based undergraduate student e-worksheets are needed. The e-worksheets in the learning process can guide students in answering and finding knowledge, especially in chemical thermodynamics. SSI-based undergraduate student e-worksheets are more practical, easily accessible, and do not require significant costs, making it a form of innovation in facilitating undergraduate students in the learning process (Aldresti et al., 2021).

Several researchers have developed SSI-based teaching materials on petroleum (Rahayu et al., 2022) and basic chemistry (Moh Ismail, 2018). In addition, research on the effectiveness of SSI-based teaching materials in increasing scientific literacy has been conducted by Rahayu et al. (2022) and Rohmah et al. (2022). Furthermore, the effectiveness of SSI-based teaching materials on pro-environmental attitudes was researched by Ma'rufah et al. (2021). These studies have never been applied to chemistry education students on chemical thermodynamic materials. Then, the effectiveness of teaching materials on scientific literacy and environmental awareness has not yet been tested.

The novelty in this study is the use of learning resources in the form of SSI-based un-

dergraduate student worksheets, specifically on chemical thermodynamics, that have not been researched based on literature studies using the Vosviewer application. Empirical findings about SSI-based teaching materials and their effectiveness in increasing scientific literacy and environmental awareness in lectures, especially on chemistry, are significant. By learning to use teaching materials, students can practice scientific literacy skills and environmental awareness that have never been done during lectures (Prasetyo et al., 2021)

Based on the description, this research aims to innovate learning by incorporating socioscientific issues relevant to everyday life into teaching materials in the form of undergraduate student e-worksheets, specifically in chemical thermodynamics. The research problems are: (1) How do SSI-based undergraduate student e-worksheets on chemical thermodynamics affect students' scientific literacy? (2) How do SSI-based undergraduate student e-worksheets on chemical thermodynamics affect students' environmental awareness?

In addition to the novelty and urgency of the research, limitations also need to be considered. First, the research was limited to Pekanbaru, Indonesia, by only involving chemistry education students at Riau University. Second, research only involves learning about chemical thermodynamics in four meetings.

METHODS

This research is pre-experimental with the static group pretest-posttest design (Sugiyono, 2019) in the chemistry education program of FKIP Universitas Riau for the 2022/2023 academic year. This study has a design with pretest and posttest (Creswell & Creswell, 2017) to determine the effect of SSI-based undergraduate student e-worksheets on chemical thermodynamics on students' scientific literacy and environmental awareness. The sample in this study is third-semester students who took the Physical Chemistry I course. This study involved 36 students: 18 experimental group students and 18 control group students (Damopolii et al., 2019).

Experimental group students learned using SSI-based undergraduate student e-worksheets. In comparison, control group students learned using science-based undergraduate student e-worksheets. The learning materials in the experimental group are outlined in a structured manner in SSI-based undergraduate student e-worksheets. Similarly, students in the control group studied structured material from science-based undergraduate student e-worksheets (Pratiwi et al., 2016).

The developed SSI-based undergraduate student e-worksheets contain social science issues about chemical thermodynamics. The application used in making SSI-based undergraduate student e-worksheets is FlipBuilder, which can make electronic books go back and forth (Winstead, 2018). SSI-based undergraduate student e-worksheets are declared feasible and valid by three material experts and three media experts. In four meetings, the experimental group used SSI-based undergraduate student e-worksheets on chemical thermodynamics with the following topics: (1) global warming; (2) plans to save Arctic ice with glass grains; (3) the use of OTEC power plants; (4) the dilemma of using air conditioning. Meanwhile, science-based undergraduate student e-worksheets contain chemical thermodynamic materials with a scientific approach (Nurkholis, 2019).

Before conducting learning, the experimental and control groups were given pretests through tests and questionnaires. After four meetings, both were given posttest through tests and questionnaires. Tests and questionnaires are used to collect data. Data on students' scientific literacy were collected through scientific literacy tests about chemical thermodynamics designed and modified by developing scientific literacy indicators by Gormally et al. (2012). The scientific literacy test consists of ten questions in the form of descriptions of chemical thermodynamics. Students' environmental awareness data was collected through a questionnaire that refers to a Likert scale assessment with four answer choices: strongly agree (4), agree (3), disagree (2), and strongly disagree (1). The environmental awareness questionnaire was designed by developing indicators of environmental awareness according to the multidimensional elaboration of environmental awareness by Sánchez & Lafuente (2010) with four dimensions: affective, cognitive, dispositional, and active. The four dimensions were developed into 20 statement items. The research instrument was validated and declared reliable by experts. The valid instruments were then tested on students' chemical thermodynamic learning.

The data obtained were analyzed using an independent sample T-test, Mann-Whitney U-test, and N-Gain test with IBM SPSS Statistic 25 application. Data was analyzed when the experimental and control groups were completed using SSI-based undergraduate student e-worksheets. The Independent Sample T-Test was conducted to determine the effect of SSI-based

undergraduate student e-worksheets on students' scientific literacy skills (Yerimadesi et al., 2023). Prerequisite tests must be met using normality and homogeneity tests. Environmental awareness questionnaire data is ordinal. Therefore, the Mann-Whitney U-test directly analyzed environmental awareness data with nonparametric statistics (Rizal et al., 2022). Improvements in scientific literacy and environmental awareness of undergraduate students were analyzed based on the difference in N-gain pretest-posttest scores between the experimental and control groups. The criteria for improving students' scientific literacy and environmental awareness are displayed in Table 1 (Hake, 1999).

Table 1. Gain Index Criteria

Score Interval	Category
$g > 0,70$	High
$0,30 < g \leq 0,70$	Medium
$g \leq 0,30$	Low

The flow chart of the research method is in Figure 1.

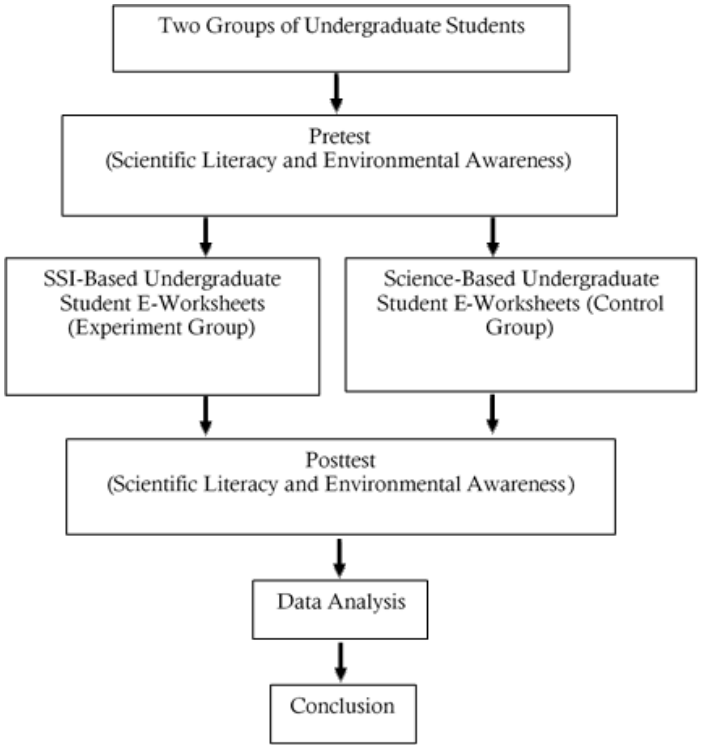

Figure 1. Research Methods

RESULTS AND DISCUSSION

This study was conducted in the experimental group and the control group. The experimental group used the developed SSI-based undergraduate student e-worksheets, while the control group used science-based undergraduate student e-worksheets. SSI-based undergraduate student e-worksheets are presented with several SSI stages: scientific background, evaluation of information, the impact of local, national, and global dimensions, and decision-making (Yuliastini et al., 2016).

Learning was carried out four times under the predetermined lesson plan for the experimental and control groups. Learning activities

through SSI-based undergraduate student e-worksheets affect students' scientific literacy. Based on the independent sample t-test, the test produces a sig value of 0.000 < 0.05, meaning SSI-based undergraduate student e-worksheets significantly affect students' scientific literacy.

Table 2. Independent-Sample T-Test for Scientific Literacy

Independent Samples Test				
		t	**df**	**Sig. (2-tailed)**
Scientific Literacy	Equal variances assumed	-11,186	34	**,000**
	Equal variances not assumed	-11,186	30,599	**,000**

An N-gain score test was carried out to determine how much the increase in scientific literacy was in both the experimental and the control groups. The increase in students' scientific literacy is presented in Table 3.

Table 3. Increase in Students' Scientific Literacy

Group	**Scientific Literacy**		**N-Gain Score**	**Category**
	Pretest	**Posttest**		
Experimental	34,77	72,44	0,57	Medium
Control	32	51,61	0,29	Low

Based on these results, it can be concluded that SSI-based undergraduate student e-worksheets provide a better increase in scientific literacy than science-based undergraduate student e-worksheets. The N-gain test results on each indicator of scientific literacy in the experimental class after using SSI-based undergraduate student e-worksheets are presented in Table 4.

Table 4. Increase in Every Scientific Literacy Indicator in the Experimental Class

No.	**Indicators**	**N-Gain Score**	**Category**
1	Use quantitative skills in problem-solving	0,52	Medium
2	Assess the application and misapplication of scientific data	0,71	Medium
3	Explain findings, estimations, and deductions through quantitative data	0,82	High
4	Analyze the reliability of the sources	0,33	Medium
5	Examine and comprehend data visualizations in graphical form	0,58	Medium
6	Determine a reliable scientific argument	0,49	Medium
7	Construct graphical data representations	0,87	High

Based on Table 4, SSI-based undergraduate student e-worksheets can improve every aspect of scientific literacy indicators. These results align with Selamet et al. (2021), where most scientific literacy indicators were in the sufficient or medium category. The highest increase in scientific literacy indicators is in indicators 3 (Justify inferences, predictions, and conclusions based on quantitative data) and 7 (Construct graphical data representations). It is possible because the e-worksheets have the scientific background stage where students are directed to observe and direct the perception that the issues presented can be solved scientifically so that they can train students to make explanations and predictions based on data (Rahmadani et al., 2018). Furthermore, at the evaluation of information stage, students are directed to explore information from various sources about the issues presented and questions that train students to make graphic representations of data. In the last or decision-making stage, students are directed to draw conclusions about the social issues of science discussed (Ladachart & Ladachart, 2021). Therefore, SSI stages can train students to provide justification, prediction, and conclusions based on quantitative data and make graphic representations of data.

The teaching materials available in universities only have content aspects and do not have attitude and context aspects, so learning is still limited to textual, not contextual (Fuadi et al., 2020). Textual chemistry learning will cause students difficulty relating their scientific knowledge to real problems and cause low scientific literacy (Rostikawati & Permanasari, 2016). Therefore, it is necessary to present teaching materials in the context of SSI that can improve students' scientific literacy.

The data shows that SSI-integrated teaching materials can improve students' scientific literacy (Ismail et al., 2016; Majetic & Pellegrino, 2018; Jufrida et al., 2019). SSI encourages students to transfer scientific thinking knowledge with skills to act in life and encourages scientific literacy skills (Imaduddin & Khafidin, 2018; Nava & Prasetyo, 2018; Sibic & Topcu, 2020). The presentation of SSI-based undergraduate student e-worksheets includes issues, problems, and questions that can trigger the ability to think and provide a decision on an issue being discussed (Tidemand & Nielsen, 2017). SSI-based undergraduate student e-worksheets provide more meaningful learning to students because the social issues used are very closely related to everyday life, so they are easier to understand and able to motivate students to explore the chemistry concepts they learn (Rostikawati & Permanasari, 2016; Rubini, 2019).

The SSI topic presented in the SSI-based undergraduate student e-worksheets is a controversial and dilemmatic chemistry-related issue. In addition to relating to the chemistry material studied, the issues presented relate to ethics and morals (Dalaila et al., 2022). The issues presented in the e-worksheets based on SSI are global warming, plans to save Arctic ice with glass grains, the use of OTEC power plants, and the dilemma of using air conditioners. These issues require students to solve problems and trigger their scientific thinking skills (Chen & Xiao, 2021). SSI-based learning will increase students' skills in considering dilemmatic social issues (Zo'bi, 2014).

On the issue of global warming, students are required to find solutions to reduce it. One of the solutions proposed by students is to save energy used in everyday life related to students' social aspects. The next is the plan to save the Arctic ice with glass grains. This issue is controversial and dilemmatic because some experts say the project plan is less efficient and cannot reduce global warming (Rau & Baird, 2018). Similarly, the issue of the use of OTEC power plants and air conditioning is controversial and dilemmatic. These issues can be resolved if students master science and social awareness to overcome problems and make decisions with full responsibility.

One of the components of scientific literacy is critical thinking, problem-solving, argument skills, and decision-making (Hestiana & Rosana, 2020; Macalalag et al., 2020). SSI-based undergraduate student e-worksheets will train students to have these skills because the e-worksheets require a reasoning process based on scientific evidence and provide a context for mastering information based on science. Based on the data analysis, sociocultural issues-based learning can be used as a context to improve scientific literacy skills.

The Mann-Whitney U Test conducted the subsequent analysis to determine the effect of SSI-based undergraduate student e-worksheets on students' environmental awareness. The results of the hypothesis test of students' environmental awareness are presented in Table 5.

Table 5. Mann-Whitney U Test for Environmental Awareness

	Environmental Awareness
Mann-Whitney U	28,500
Wilcoxon W	199,500
Z	-4,230
Asymp. Sig. (2-tailed)	,000

Table 5 shows that the sig value < 0.05, meaning that the developed SSI-based undergraduate student e-worksheets affect students' environmental awareness. Differences in students' environmental awareness in the control and experimental groups after using SSI-based undergraduate student e-worksheets are presented in Table 6.

Table 6. The Difference in Environmental Awareness

Group	Environmental Awareness		N-Gain Score	Category
	Pretest	Posttest		
Experimental	49	69	0,67	Medium
Control	47	56	0,28	Low

The data analysis shows that students who used SSI-based undergraduate student e-worksheets have higher environmental awareness than those who used science-based e-worksheets. This is because learning using SSI-based e-worksheets presents environmental issues that train students' environmental awareness. This statement aligns with Ma'rufah et al. (2021), who state that teaching materials based on socioscientific issues effectively increase pro-environmental attitudes. N-gain test results on each environmental awareness indicator in the experimental class after using SSI-based undergraduate student e-worksheets are presented in Table 7.

Table 7. Improvement of Every Environmental Awareness Indicator in the Experimental Class

No.	Indicators	N-Gain Score	Category
1	Concern for the environment	0,68	Medium
2	Support for adopting environmental solutions to address specific and global issues	0,63	Medium
3	The perception that the environment is a serious threat if not properly maintained	0,63	Medium
4	Individual information and knowledge of environmental issues	0,65	Medium
5	Individual involvement from the perspective of feelings of self-efficacy and responsibility	0,69	Medium
6	Positive attitudes towards various pro-environmental attitudes are reflected in the willingness to bear the personal costs of environmental actions	0,65	Medium
7	Individual involvement in high- and low-cost pro-environmental attitudes	0,62	Medium

SSI-based undergraduate student e-worksheets in learning can improve every aspect of environmental awareness indicators. The increase in the seven indicators of environmental awareness gets the medium category. Environmental awareness includes knowledge, student sensitivity in the form of attitudes, and willingness to act to preserve the environment (Nuraini et al., 2022). Increasing environmental awareness can stimulate students' self-development through awareness of their responsibility for environmental issues (Chen et al., 2020).

Chemistry learning using SSI-based undergraduate student e-worksheets raises environmental issues of global warming. The SSI-based undergraduate student e-worksheet activities introduce students to global warming's causes and effects. The cause of global warming is the combustion of fossil fuels (Talib, 2014), and the impact is the melting of polar ice. In addition to providing knowledge about environmental issues, SSI-based e-worksheets also direct students to investigate these environmental issues further. Students are asked to discuss finding solutions and participate in dealing with these environmental problems. The discussion activity can hone environmental awareness (Karahan & Roehrig, 2015)

Environmental issues discussed in SSI-based undergraduate student e-worksheets will make students more familiar with current environmental conditions to be aware of their role as a community in protecting the environment. In this study, environmental awareness is reflected in the attitude and willingness of students to take concrete actions to protect the environment. Some of the actions proposed by students from SSI-based e-worksheets to protect the environment are reducing the use of fossil fuels, saving energy, and using renewable energy. Based on the activities in the e-worksheets and the data ana-

lysis, learning with SSI-based undergraduate student e-worksheets affects and improves all indicators of students' environmental awareness.

Based on the study results, SSI-based undergraduate student e-worksheets can simultaneously increase two outcome variables: scientific literacy and environmental awareness, especially in chemical thermodynamics. SSI-based undergraduate student e-worksheets can help students improve their scientific literacy skills and environmental awareness.

CONCLUSION

Learning activities SSI-based undergraduate student e-worksheets can increase chemistry education students' scientific literacy and environmental awareness, especially on chemical thermodynamics. SSI-based e-worksheets on chemical thermodynamics in learning can improve scientific literacy and environmental awareness indicators. The environmental issues presented in the SSI-based e-worksheets trigger students' critical thinking skills and awareness of current environmental conditions. In addition, the stages in SSI-based e-worksheets require students to solve problems and find solutions. Researchers recommend SSI-based undergraduate student e-worksheets on chemical thermodynamics to increase scientific literacy and environmental awareness.

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