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THE USE OF SOCIO-SCIENTIFIC ISSUES TO PROMOTE PROSPECTIVE BIOLOGY TEACHERS' SCIENTIFIC LITERACY AND RESEARCH SKILL DEVELOPMENT

M. Haviz*[1], E. Nasrul[1], D. Azis[2], I. M. Maris[3], F. Wahyudi[1]

[1]Department of Biology Education, Universitas Islam Negeri Mahmud Yunus Batusangkar, Indonesia
[2]Department of Islamic Education, Universitas Islam Negeri Mahmud Yunus Batusangkar, Indonesia
[3]Department of Mathematics, Universiti Pendidikan Sultan Idris, Malaysia

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ABSTRACT

This study aims to investigate the use of SSI to promote prospective biology teachers' scientific literacy and research skill development. This research uses quantitative methods with a true-experiment design. The treatments were Guided Inquiry (GI) and Research-based Learning (RbL) in two biology classes. This study involved 39 sixth-semester students, five males and 34 females. The lecturer applied the GI and RbL syntax at the 1-8th meetings to collect the data. At the 9-12th meeting, PBTs carried out guided work by studying articles containing themes or content of SSI from the scientific journal. Data analysis was carried out with descriptive statistics, and to differentiate between the two treatments, a test of equality of mean values was carried out using the t-test. This research provides several conclusions. First, SSI articles can be used as learning materials promoting scientific literacy and RSD-7. Second, using SSI with RbL and SSI with GI promotes prospective biology teachers' scientific literacy. The SL components are explaining phenomena scientifically, evaluating and designing inquiry, interpreting data, and knowledge of scientific literacy. Third, using SSI with RbL and SSI with GI promotes prospective biology teachers' RSD-7 skills at all levels: (1) Embark and Clarify, (2) Find and Generate, (3) Evaluate and Reflect, (4) Organize and Manage, (5) Analyze and Synthesize, and (6) Communicate and Apply. The seven levels in RSD-7 are prescribed research, bounded research, scaffolded research, self-initiated research, open research, adopted research, and enlarging research. There were no differences in RSD-7 skills between the SSI with RbL and GI treatments. Fourth, there is no difference in learning outcomes between the SSI with GI and RbL treatments.

Keywords: socio-scientific issues; scientific literacy; research skill development; prospective biology teachers

INTRODUCTION

Scientific literacy (SL) is a crucial topic to discuss as part of 21st-century skills in higher education (Geisinger, 2016; Haviz, 2018; Haviz et al., 2018, 2020; Hanifha et al., 2023). Many previous research studies explain that students must have scientific literacy when learning biology. Tsunekage et al. (2020) aim to integrate information literacy into general biology learning modules, and the results show that students' information literacy skills increase in line with the use of learning modules. In line with this research, Borchardt et al. (2019) have also developed and tested the effectiveness of a general biology practicum module that includes students' literacy skills and found that students' scientific literacy skills increased after using the learning module. Previous study was conducted to explore scientific literacy skills in biology learning, such as health literacy in middle school students (Suwono et al., 2023a), the central dogma of biology (Silveira et al., 2023), ethological techniques and place-based pedagogy (Ambrosino & Rivera, 2022), bioscience laboratory (Rolfe & Adukwu, 2023), and algae photosynthesis and respiration experimentation (Wildan et al., 2022).

*Correspondence Address
E-mail: mhaviz@uinmybatusangkar.ac.id

Students in higher education need research skill development (RSD) because research is one of the main activities that students in higher education must carry out. The previous research shows that there is quality learning in higher education. For this reason, students in higher education need to have research skills, and lecturers are interested in helping students have research skills. Previous research shows that research skills are needed by graduates in looking for work (Ain et al., 2019). Furthermore, Willison (2012) also explains that when research skills are integrated into the curriculum, it is beneficial for students to solve various problems they face while studying inside or outside the classroom. Previous studies also show benefits and positive results from integrating RSD into the biology learning process. For example, Salybekova et al. (2021) conducted students' research skills development through project-based learning in biology and showed the importance of the relationship between educational and research activities of students. Kang et al. (2022) identified possible threshold concepts using an extensive data set from the biological sciences, and the findings demonstrate the strategy's effectiveness, as well as convergence between results of the current study and more conventional, qualitative results identifying threshold concepts at the doctoral level.

Previous research has shown that RSD is beneficial for students. For example, Perez et al. (2022) show that students' research skills improved after lecturers were assisted and guided in completing and publishing their research articles. Furthermore, Willison and Buisman-Pijlman (2016) have researched the effectiveness of implementing the research skills development model in undergraduate classes in Australia. The research was conducted using case studies in health science programs, and the findings show that students benefit from using the RSD framework. Subsequent studies about research skill development were conducted, such as the study about how to improve work skill development by using research skill development (Bandaranaike, 2018), the integration of research skill development to improve thinking skills (Mataniari et al., 2020), and effectiveness of postgraduate research skills training and its alignment with the research skill development framework (Gyuris, 2018). These articles clearly and transparently provide positive results for improving student research skills.

Socio-Scientific Issues (SSI) is a teaching approach that can be used as creative teaching in studying biology (Suwono et al., 2023a; Suwono et al., 2023b). This research also shows SSI has improved secondary school students' literacy skills, knowledge, and critical thinking. Presley et al. (2013) show that SSI learning is a supportive strategy for developing SL skills. The use of SSI in biology learning can increase abilities, awareness, argumentation, and the ability to make decisions from a social, political, and scientific perspective (Sadler, 2005; Sadler et al., 2006; Sadler, 2011). The following studies also showed that using SSI improves students' achievement in biology learning (Lee, 2007; Gertner et al., 2023). Referring to the research results described, SSI is thought to be used to develop other skills simultaneously. The special features of SSI have opportunities to investigate whether using SSI with specific learning methods can give rise to other skills. The next previous study showed the use of socio-scientific issues in biology, such as the interpretation and implementation of socio-scientific issues in biology teaching (Tidemand & Nielsen, 2017), development and validation of an instrument for assessing high-school students' perceptions of socio-scientific issues (Subiantoro & Treagust, 2021), science content through socio-scientific issues-based instruction (Sadler et al., 2016), and socio-scientific issues from genetics (Lederman et al., 2014). This study investigates using SSI to promote SL and RSD skills simultaneously in biology learning. It is suspected that inquiry learning and research-based learning methods can simultaneously promote SL and RSD skills.

Two learning theories underlie the implementation of this research: cognitive and constructivist theories. The cognitive theory covers human development, adaptation, and change (Bandura, 2002). Constructivism theory can make students construct and practice their knowledge (Piaget, 1977). Both theories were used to construct design research related to SL and RSD. Also, the basic framework for using SSI to promote SL and RSD was designed based on previous research results. Presley et al. (2013) show that SSI design in science learning is structured based on three aspects: design elements, learner experience, and teacher attributes, which work together to form variations in learning classes. These three aspects are critical components forming the SSI framework for promoting SL and RSD. The classroom environment aspect functions as a wrapper for this framework. Sadler (2011) also detailed these three aspects: the design element characterized by learning activities, engaging problem-based learning, and presenting the problem. First, there is a high level of practice in argumentation, reasoning, and decision-making activities, as well as a high level of experience for students. Second, students' experiences are characterized by activity; there is a high level of practice in reasoning, argumentation, decision-making, presentation of scientific ideas and theories related to the problem being studied, collection and analysis of scientific data related to the problem being discussed, negotiation of problems in the social dimension, for example, politics and economy. Third, teachers' attributes are familiar with issues currently being discussed. Teachers also act as students by having an honest attitude towards limited knowledge, a willingness to position themselves as knowledge contributors rather than sole authorities, and a willingness to face uncertainty in the classroom.

Regarding the use of SSI research, Hancock et al. (2019) show evidence and confirmation regarding the use of issues that teachers have selected, and these issues are given to students as content in the learning process. These findings show an opportunity to use various issues from many sources as content in the learning process. Vieira and Tenreiro-Vieira (2016) explained that teachers can apply appropriate learning strategies by participating in discussions, writing articles, and analyzing articles that examine controversial socio-scientific issues. The previous explanations show opportunities for learning activities using SSI content to promote students' SL and RSD.

However, previous studies do not clearly show the use of learning steps or syntax to develop SL and RSD skills. This condition contributes to the use of syntax that is thought to be appropriate and supports learning activities to generate SL and RSD. If examined from social learning theory and constructivism, research-based and guided inquiry learning syntaxes are thought to fulfill the learning activities previously described by researchers. Thus, to promote specific learning skills, it is necessary to apply learning methods with activities relevant to the skills that students are expected to develop and possess. In this research, SL and RSD are skills expected to emerge and be mastered by students who undergo the learning process. This study applied guided inquiry and research-based learning. Therefore, this research uses inquiry as a learning method that can promote learning skills and activities in biology.

According to PISA, scientific literacy (SL) is the ability to engage with issues related to science and scientific ideas as a reflective citizen. To identify SL, students must (1) explain phenomena scientifically; identify, analyze, and evaluate scientific phenomena; (2) evaluate and design scientific inquiry; explain and evaluate and propose scientific answers; and (3) interprete data and evidence scientifically; analyze and evaluate data; and conclude. These skills require knowledge of content, procedural, and epistemic (OECD, 2018).

Research Skill Development (RSD) is an approach to improving the students' research skills. How to start and determine the research process in RSD-7 refers to aspects of research and seven levels of students' autonomy. The aspects of this research consist of (1) Embark and Clarify: The researchers begin the research, determine and clarify requirements (knowledge, team, ethical, and the like); (2) Find and Generate: The researchers find and produce the information using the relevant methodology; (3) Evaluate and Reflect: The researchers evaluate and reflect information and data; (4) Organize and Manage: The researchers organize and manage information, data, and team; (5) Analyze and Synthesize: The researchers analyze information and data and synthesize new knowledge; (6) Communicate and Apply: The researchers give information and respond to feedback from others (Willison & O'Regan, 2007; Ain et al., 2019).

The following are activities at seven levels of students' autonomy: (1) Prescribed Research: The supervisor provides guidance, and student-researchers follow it; (2) Bounded Research: Student-researchers require some initial knowledge to choose one of two methods; (3) Scaffolded Research: Supervisor assesses parameters, but the student-researchers must determine their activity; (4) Self-initiated Research: Student-researchers design their research under the supervisor; (5) Open Research: Student-researchers initiate and determine their research; (6) Adopted Research: Student-researchers determine the direction of their research. The research results are expected to be used and adopted by other people, for example, by citing and adopting methodology and research results or gaps that students have identified; (7) Enlarging Research: Student-researchers reconceptualize research topics within the team that make extensive contributions or are widely used. Thus, individual contributions are combined into something more significant.

This study aims to (1) identify the use of socio-scientific issues from articles in biology learning, (2) investigate the use of socio-scientific issues with guided inquiry for promoting prospective biology teachers' scientific literacy, (3) investigate the use of socio-scientific with research-based learning for promoting prospective biology teachers' scientific literacy, and (4) investigate the use of socio-scientific issues with guided inquiry and research-based learning to student achievement.

METHODS

This research uses quantitative methods (Creswell & Creswell, 2018). The research design was a true experiment, with research-based learning (RbL) as the first treatment and guided inquiry (GI) as the second. The variables investigated were scientific literacy (SL), research skill development (RSD), and student achievement. This research involved prospective biology teachers at Islamic University from the Department of Biology Education UIN Mahmud Yunus Batusangkar in Indonesia for the 2022/2023 academic year. Prospective biology teachers in this study were 39 sixth-semester students, five males and 34 females. Students were grouped into two classes based on initial abilities verified before the research was conducted.

To collect the data, research participants were taught by the same lecturer and teaching method in the Scientific Literacy course. Face-to-face lecture meetings were held 16 times within one semester. The content provided was scientific literacy and online research skills, and students studied them under guidance from the lecturer. At the 1st-8th meeting, the lecturer applied the GI and RbL learning syntaxes. The stages in guided inquiry learning are (1) introduction, where the lecturer conveys the learning objectives; (2) opening, where the lecturer gives students examples and asks students to learn and criticize them; (3) meeting, where the lecturer conveys questions to discuss in-depth, (4) closing and application, where the lecturer guides students to achieve concept and new knowledge (Downs, 1988). The stages in research-based learning are (1) facing the issue, where students obtain and study the issues; (2) data collection-verification, where students collect issues; (3) data collection-experimentation, where students find important topics or problems; (4) explanation formulation, where students formulate answers to the problems; (5) research analysis, where students analyze the answers (Haviz, 2018).

At the 9-12th meeting, students carried out guided work by studying articles with themes or content of socio-scientific issues from the Journal of Biological Education (Taylor and Francis Online). The lecturer has prepared and determined the article. Each student studied different articles. Students wrote answers to the questions included in the instrument. They answered these questions based on the articles they studied. The lecturer assessed the answer sheets and used them as research data. Furthermore, at the 13th-16th meeting, the lecturer evaluated the application of learning methods and held the final semester exam. The final semester exam questions were designed based on scientific literacy content.

This research used three instruments: scientific literacy skills, research skills development, and student achievement tests. The following are indicators of SL: (1) explaining phenomena scientifically, (2) evaluating scientific phenomena, (3) designing queries and interpreting data, and (4) knowledge of scientific literacy (OECD, 2018). The indicators of RSD are aspects of research: (1) embark and clarify, (2) find and generate, (3) evaluate and reflect, (4) organize and manage, (5) analyze and synthesize, and (6) communicate and apply (J. Willison et al., 2018). The instrument also consists of seven levels of students' autonomy: prescribed research, bounded research, scaffolded research, self-initiated research, open research, adopted research, and enlarging research. The student achievement test was designed based on SL content from PISA documents (OECD, 2018): (1) introduction: scientific literacy and why it matters; (2) scientific literacy: towards a definition; (3) organization of the domain, (4) assessment of the domain and (5) online research skill. Experts validated the three instruments, and the result showed that the instrument can be used to collect the data in the research. The data were analyzed with descriptive statistics (Kaur et al., 2018). To differentiate between the two treatments, a test of equality of mean values was carried out using the t-test. Then, this data was interpreted by providing descriptions, explanations, and arguments per the research (Toutenburg, 2009).

RESULTS AND DISCUSSION

This research used articles as a source for socio-scientific issues. These articles are published in the Journal of Biological Education by Taylor & Francis. Based on data on Scopus, the Journal of Biological Education is ranked Q2 with Sjr 0.5. This journal has a scope in biology education/learning for all ages, connecting teachers, researchers, and educators in a joint effort to improve biology education internationally.

Researchers used the search engine with the keyword "Literacy" to determine the articles prospective biology teachers review so that the articles that appear are only related to literacy issues. Next, the year filter was also applied, so only articles published from 1-1-2019 to 12-31-2021 were selected and used as study material. From this step, 45 articles containing or studied literacy were obtained. Only 39 articles were randomly selected or adjusted to the number of research participants. The articles reviewed by prospective biology teachers are listed in Table 1 dan Table 2.

Table 1. Socio-Scientific Issues Articles Reviewed by Research-based Learning Class

No	Article
1	Hadi Suwono, Tutut Permana, Muhammad Saefi & Rifka Fachrunnisa (2021). Biology problem-based learning (PBL) to increase health literacy in middle school students. Journal of Biology Education, 57:1, 230-244. DOI: 10.1080/00219266.2021.1884586
2	Daniel Gertner, Na Xu, Holly Porter-Morgan & Jacqueline Brashears (2021): Developing students' scientific literacy through an e-portfolio project at a community college gateway science course. Journal of Biological Education, 57:1, 129-144. DOI: 10.1080/00219266.2021.1877782
3	Oier Pedrera, Unai Ortega, Aritz Ruiz-González, José Ramón Díez & Oihana Barrutia (2021): Branches of plant blindness and their relationship with biodiversity conceptualisation among secondary students. Journal of Biological Education, 57:3, 566-591. DOI: 10.1080/00219266.2021.1933133

4 Ian M. Kinchin & Alfred E. Thumser (2021): Mapping the 'becoming-integrated-academic': an autoethnographic case study of professional becoming in the biosciences. Journal of Biological Education, 57:4, 715-726. DOI: 10.1080/00219266.2021.1941191

5 Gavin R. Owen, Natalie Whalley & Elisabeth Brenner (2021): Lost in 'translation'? A set of writing workshops improves Molecular Medicine Honours students' perceptions of their scientific report writing skills. Journal of Biological Education, 57:3, 647-667. DOI:10.1080/00219266.2021.1941186

6 Kristi Brownlee, Kathryn M. Parsley & Jaime L. Sabel (2021): An Analysis of plant awareness disparity within introductory Biology textbook images. Journal of Biological Education, 57:2, 422-431. DOI: 10.1080/00219266.2021.1920301

7 Fayadh Hamed Alanazi (2021): Saudi students' and science teachers' knowledge of and attitudes towards biotechnology. Journal of Biological Education, 57:1, 196-213. DOI: 10.1080/00219266.2021.1884584

8 Vivien Rolfe & Emmanuel Adukwu (2021): Bioscience laboratory practicals, projects and placements in a Covid-19 world. Journal of Biological Education, 57:3, 668-677. DOI: 10.1080/00219266.2021.1941187

9 Lucas Fagundes Silveira, Christian Santos Xavier, Maíra Alexandre Perez, Dandie Antunes Bozza, Lupe Furtado-Alle, Iris Hass & Luciane Viater Tureck (2021): unravelling the central dogma of Biology in an active way: a case study. Journal of Biological Education, 57:1, 101-114. DOI: 10.1080/00219266.2021.1877780

10 Jairo Robles-Piñeros & Luca Tateo (2021): Isn't all about trash... Children's conceptions about ecology and their implications for biology education in Colombia. Journal of Biological Education, 57:3, 692-705. DOI: 10.1080/00219266.2021.1941189

11 Gabriel de Moura Silva, Daniel J. G. Lahr & Rosana Louro Ferreira Silva (2021): The epistemic and pedagogical dimensions of evolutionary thinking in educational resources for zoology designed for preservice teacher education. Journal of Biological Education, 57:1, 115-128. DOI: 10.1080/00219266.2021.1877781

12 Markéta Machová & Edvard Ehler (2021): Secondary school students' misconceptions in genetics: origins and solutions. Journal of Biological Education, 57:3, 633-646. DOI: 10.1080/00219266.2021.1933136

13 Lidia Caño & Unai Ormazabal (2021): Basque secondary school students' understanding of natural selection and teleological reasoning: knowledge vs. knowledge application. Journal of Biological Education, 57:3, 537-554. DOI: 10.1080/00219266.2021.1933131

14 Merve Coban & Bayram Coştu (2021): Integration of biomimicry into science education: biomimicry teaching approach. Journal of Biological Education, 57:1, 145-169. DOI: 10.1080/00219266.2021.1877783

15 Tamara Esquivel-Martín, Beatriz Bravo-Torija & José Manuel Pérez-Martín (2021): Solving a problem about cancer treatment: how does the use of the mitotic spindle model evolve during small group discussions? Journal of Biological Education, 57:3, 469-483. DOI: 10.1080/00219266.2021.1924230

16 Anushree Bopardikar, Debra Bernstein & Susan McKenney (2021): Designer considerations and processes in developing school-based citizen-science curricula for environmental education. Journal of Biological Education, 57:3, 592-617. DOI: 10.1080/00219266.2021.1933134

17 Tuomas Aivelo, Eva Neffling & Maija Karala (2022): Representation for whom? Transformation of sex/gender discussion from stereotypes to silence in Finnish biology textbooks from 20th to 21th century. Journal of Biological Education, DOI: 10.1080/00219266.2022.2047099

18 Nikki T. Donegan, Jocelyn M. Zachariah & Jeffrey T. Olimpo (2022): Integrating Museum education into an introductory biology CURE leads to positive perceptions of scientific research and museum exhibitions among students, faculty, and staff. Journal of Biological Education, DOI: 10.1080/00219266.2022.2103168

19 Lilin Tong, Bethany J. G. White & Jastaranpreet Singh (2022): Bridging statistics and life sciences undergraduate education. Journal of Biological Education, DOI:10.1080/00219266.2022.2118810

20 Chloe Wasendorf, Joshua W. Reid, Rebecca Seipelt-Thiemann, Z. T. Grimes, Brock Couch, Nick T. Peters, Julia Massimelli Sewall, Audrey L. McCombs, Patrick I. Armstrong & Nancy Boury (2022): the development and validation of the mutation criterion referenced assessment (MuCRA). Journal of Biological Education, DOI: 10.1080/00219266.2022.2100451

21 Alexandros Amprazis, Penelope Papadopoulou & George Malandrakis (2019): Plant blindness and children's recognition of plants as living things: a research in the primary schools context. Journal of Biological Education, 55:2, 139-154. DOI: 10.1080/00219266.2019.1667406

22 Gahyoung Kim & Hyunju Lee (2019): A case study of community-based socio-scientific issue program: focusing on the abandoned animal issue. Journal of Biological Education, 55:4, 380-394. DOI: 10.1080/00219266.2019.1699150

23 Anna Solé-Llussà, David Aguilar & Manel Ibáñez (2019): Video worked examples to promote elementary students' science process skills: a fruit decomposition inquiry activity. Journal of Biological Education, 55:4, 368-379. DOI: 10.1080/00219266.2019.1699149

Table 2. Socio-Scientific Issues Articles Reviewed by Guided Inquiry Class

No	Article
1	Christine M. Ambrosino & Malia Ana J. Rivera (2020): Using ethological techniques and place-based pedagogy to develop science literacy in Hawai'i's high school students. Journal of Biological Education, 56:1, 3-13. DOI: 10.1080/00219266.2020.1739118
2	İsa Deveci & İbrahim Karteri (2020): Context-based learning supported by environmental measurement devices in science teacher education: A mixed method research. Journal of Biological Education, 56:5, 487-512. DOI: 10.1080/00219266.2020.1821083
3	Saad Qureshi (2020): How students engage in biomimicry. Journal of Biological Education, 56:4, 450-464. DOI: 10.1080/00219266.2020.1841668
4	Justus Mutanen & Anna Uitto (2020): Make biology relevant again! Pre-service teachers' views on the relevance of biology education. Journal of Biological Education, 54:2, 202-212. DOI: 10.1080/00219266.2020.1739423
5	Irene Angosto Sánchez & Juan Gabriel Morcillo Ortega (2020): Teaching vegetable nutrition: From the problem to the proposal. Journal of Biological Education, 56:4, 417-43. DOI: 10.1080/00219266.2020.1808514
6	Dianne J. Watters, Peter R. Johnston, Christopher L. Brown & Wendy A. Loughlin (2020): Undergraduate biochemistry student difficulties with topics requiring mathematical skills: Use of an online maths skills support site. Journal of Biological Education, 56:2, 130-146. DOI: 10.1080/00219266.2020.1757484
7	Esther Cascarosa, Beatriz Mazas & Ester Mateo (2020): Are early-years-children able to use magnifying glasses and dichotomous keys to observe, compare, classify and identify small animals? Journal of Biological Education, DOI: 10.1080/00219266.2020.1776753
8	Tim Heemann & Marcus Hammann (2020): Towards teaching for an integrated understanding of trait formation: an analysis of genetics tasks in high school biology textbooks. Journal of Biological Education, DOI: 10.1080/00219266.2020.1739421
9	Ardan Wildan, Chin Doong Yau, Enoch Ming Wei Ng, Kevin Xiao, Oi Wah Liew & Tuck Wah Ng (2020): Algae photosynthesis and respiration experimentation with physical and augmented reality modes. Journal of Biological Education, 56:2, 222-241. DOI: 10.1080/00219266.2020.1757487
10	Susanne Walan (2020): Pre-service teachers' reflections when drama was integrated in a science teacher education program. Journal of Biological Education, 56:2, 208-221. DOI: 10.1080/00219266.2020.1776751
11	Nina Meyerhöffer & Daniel C. Dreesmann (2019): Expert video exchanges in bilingual biology lessons - student's intrinsic motivation and subject-specific interest. Journal of Biological Education, 54:3, 315-327. DOI: 10.1080/00219266.2019.1575265
12	Toshi Tsunekage, Christopher R. Bishop, Casey M. Long & Iris I. Levin (2019): Integrating information literacy training into an inquiry-based introductory biology laboratory. Journal of Biological Education, 54:4, 396-403. DOI: 10.1080/00219266.2019.1600569
13	Rachel Borchardt, Tovah Salcedo & Meg Bentley (2019): Little intervention, big results: Intentional integration of information literacy into an introductory-level biology lab course. Journal of Biological Education, 53:4, 450-462, DOI: 10.1080/00219266.2018.1494029
14	Damir Sirovina & Goran Kovačević (2019): Importance of an appropriate visual presentation for avoiding a misconception of the menstrual cycle. Journal of Biological Education, 53:3, 302-309, DOI: 10.1080/00219266.2018.1469539
15	Gahyoung Kim & Hyunju Lee (2019): A case study of community-based socio-scientific issue program: focusing on the abandoned animal issue. Journal of Biological Education, 55:4, 380-394. DOI: 10.1080/00219266.2019.1699150
16	Andreas Ch. Hadjichambis, Yiannis Georgiou, Demetra Paraskeva Hadjichambi, Eleni A. Kyza, Andria Agesilaou & Demetrios Mappouras (2019): Promoting RRI and active citizenship in an inquiry-based controversial socio-scientific issue: the case of cholesterol regulation with statins. Journal of Biological Education, 53:5, 548-560, DOI: 10.1080/00219266.2018.1530277

The scores for the mean and standard deviation of SSI to promote prospective biology teachers' scientific literacy are displayed in Table 3. The finding shows that the mean score for SSI with RbL is higher than that for GI. This finding also shows that the mean score is at a good level. The mean for explaining phenomena scientifically is 3.53, evaluating and designing inquiry is 3.25, and interpreting data is 3.41. These data are supported by the results of prospective biology teachers' activity. Descriptions of prospective biology teachers' activities are presented in the following section.

Table 3. Mean and Standard Deviation of Prospective Biology Teachers' Scientific Literacy

Treatment	Scientific Literacy					
	Explaining Phenomena Scientifically		Evaluating and Designing Inquiry		Interpreting Data	
	M	SD	M	SD	M	SD
SSI with RbL	3.53	0.65	3.25	0.52	3.41	0.65
SSI with GI	3.15	0.61	3	0.49	3.13	0.49

Note: Poor (1); Fair (2); Good (3); Excellent (4)

Prospective biology teachers must answer questions 1 to 7 regarding explaining phenomena scientifically to reveal their skills. In the following section, research findings on this matter are explained. *Q1#. Write down the title, author's name, journal identity, and type/field of research for the article you are reviewing!.* All prospective biology teachers answered this question correctly. They identified the title, author's name, identity, and type of research from the articles they reviewed. The following is an example of their answer. "Sirovina, D., & Kovačević, G. (2019). Importance of an appropriate visual presentation for avoiding a misconception of the menstrual cycle. Journal of Biological Education, 53(3), 302-309. doi: 10.1080/00219266.2018.1469539"

Q2#. What is the research problem in the article?. Almost all prospective biology teachers correctly identified the problems in the articles they reviewed. However, several prospective biology teachers were not good at finding and identifying problems from the articles. The following is an example of their answer. "Misconceptions were found during the menstrual cycle, fertility, and ovulation. Misconceptions regarding menstrual bleeding are taught using images that do not change."

Q3#. Does the author explain why this problem is important as a research topic?. Prospective biology teachers successfully identified why the problem is important as a research topic. However, not all of the prospective biology teachers identified them well. The following is an example of their answer. "The author believes that it is important to evaluate the effect of using appropriate visuals in teaching the menstrual cycle to high school students to improve students' understanding of the menstrual cycle and avoid common misunderstandings related to the menstrual cycle and fertile days or ovulation."

Q4#. Does the author describe quantitative or qualitative data to support the importance of the research problem?. All prospective biology teachers answered this question correctly. They successfully identified data supporting the arguments presented by the author. The following is an example of their answer. "In the article, the author describes data that supports the problem, such as diagrams, the initial and final tests, and arguments about misunderstandings among students in determining ovulation."

Q5#. Does the author describe the research results relevant to the research problem? If yes, write down relevant sources!. Prospective biology teachers successfully found and described the relevant sources for the conducted research. They also identified relevant research literature. The following is an example of their answer. "Yes, the author describes the research results relevant to the problem. One example is when the author included research results that using three different menstrual cycle diagrams for teaching high school students can improve students' understanding of the menstrual cycle and avoid common misunderstandings related to the menstrual cycle and fertile days or ovulation: "The results showed that the use of three different menstrual cycle diagrams in teaching menstrual cycle to high school students significantly improved their knowledge and understanding of the menstrual cycle. The students taught using three diagrams showed better adoption of facts and concepts related to the menstrual cycle compared to those taught using only one diagram." (Sirovina and Kovacevic, 2018).

Reference: Sirovina, D., & Kovacevic, G. (2018). The Effect of Using Different Menstrual Cycle Diagrams on High School Students' Knowledge and Misconceptions about Menstruation. Health Education Journal, 77(7), 862-872.

Q6#. Does the author find similarities and differences between their research and previous research?. Not all prospective biology teachers answered this question correctly. Some of them did not answer this question. The following is an example of their answer.. "Yes, this research uses the material about the 28-day menstrual cycle diagram to test the initial knowledge level."

Q7#. Do the authors include identification, problem formulation, and/or research objectives in the articles?. All prospective biology teachers successfully identified the problem formulation and/or research objectives from the articles they reviewed. The following is an example of their answer. "The research problem is stated in the introduction section and explained further in the research objectives outlined in the methodology section. The author highlights that misunderstandings about the menstrual cycle are still common among students studying biology. The authors also highlight that inappropriate use of visual media can exacerbate students' misunderstandings about the menstrual cycle."

The problem formulation in the article is stated indirectly. An example with the problem formulation obtained is (a) How can misunderstandings related to the menstrual cycle affect students' understanding of biology learning? (b) How can using appropriate visual media help avoid students' misunderstandings about the menstrual cycle? (c) How can increasing visual literacy improve the effectiveness of biology teaching to students? (d) How can implementing appropriate use of visual media help increase students' understanding of the menstrual cycle and correct misunderstandings? (e) How can the importance of using appropriate visual media in biology teaching be achieved and measured objectively?. Prospective biology teachers must answer questions 8 to 9 regarding interpreting data and evidence scientifically to reveal their skills. In the following section, research findings on this matter are explained.

Q8#. Write down the research results of the article! All prospective biology teachers successfully identified the research results of the articles they reviewed. The following is an example of their answer. "The results show students with the correct answers: (a) 16% of students in 30-day cycle class, (b) 53% of students in 32-day cycle class, and (c) 88.64% of students in 34-day cycle class."

Q9#. Did the author analyze and discuss the research findings?. All prospective biology teachers successfully identified the discussion and analysis of the articles they reviewed. The following is an example of their answer. "Yes, the author analyzed and discussed the research findings. The author carried out statistical analysis using several data analysis techniques, such as the Kruskal-Wallis ANOVA test, Median test, Multiple comparisons test, and chi-square test. The analysis results showed significant differences in the answers of students from the four groups. Students taught using three menstrual cycle diagrams showed better adoption of facts and concepts than those taught using one menstrual cycle diagram. The discussion was carried out by linking the research results with relevant literature, such as previous research on the importance of visual literacy in biochemistry education and the importance of using modern teaching methods and multimedia tools in education. The author also discussed the implications of the findings of this research, where the use of appropriate visuals in teaching the menstrual cycle is very important to avoid misunderstandings and increase the visual literacy of students and teachers." Prospective biology teachers must answer questions 10 to 11 regarding evaluating and designing scientific inquiry to reveal their skills. In the following section, research findings on this matter are explained.

Q10#. Write down the type of research from the article you reviewed! Why? Explain your argument!. All prospective biology teachers successfully identified the type of research used by the author. They also examined the author's arguments regarding the research methods used in the article. The following is an example of their answer. "This research is quantitative because there is a pretest and posttest after teaching students. This article has an experimental research type. This research was conducted by comparing the learning outcomes of students taught using three different menstrual cycle diagrams with those taught using standard menstrual cycle diagrams. Apart from that, this research also uses pretests and final exams to collect data and conduct statistical evaluations to determine differences between different groups of students."

Q11#. Describe the research procedures and data analysis techniques!. Only some prospective biology teachers correctly identified the research procedures and data analysis techniques. The following is an example of their answer. "This research involved 190 students aged 17-18 from different schools. The percentage of women is 73%. This article also explained that each teacher teaches the menstrual cycle to different classes. Tests were carried out at the beginning and end of the learning to determine learning outcomes. The author used several data analysis techniques: (a) Kruskal-Wallis ANOVA and Median test, used to determine statistically significant differences in students' answers from four different groups; (b) Multiple Comparisons test, used to compare the differences between two different groups of students before and after the lesson; (c) Chi-square test, used to test differences in the percentage of correct or incorrect answers between each pair of student groups tested; (d) Frequency table, used to assess the number and percentage of correct or incorrect answers in each group of students tested. The author used a non-parametric approach because the variables used were categorical, and there were more than two groups. Apart from that, Statistica 11.0 software was used to carry out statistical evaluations on the data collected".

Prospective biology teachers must write down the context, knowledge, and competencies based on their article review to reveal their skills. This research finds that (1) The use of SSI with RbL and GI promotes the skills of explaining phenomena scientifically; (2) The use of SSI with RbL and GI promotes the evaluating and designing inquiry skills; (3) The use of SSI with RbL and SSI with GI promotes the data interpreting skills, and (4) The use of SSI with RbL and SSI with GI promotes the knowledge on scientific literacy.

The results of using SSI on prospective biology teachers' research skill development are displayed in Table 4. The results show that the mean of aspects of research in the SSI with RbL class is higher than in the SSI with GI class. For example, the mean score for the curious aspect was 2.57 in SSI with RbL and 2.75 in GI. These findings show that using SSI with RbL and SSI with GI can promote aspects of prospective biology teachers' research skills. If interpreted qualitatively, all the aspects of the research skills are in good and excellent categories (except for Embark and Clarify, which is at a fair level).

Table 4. Mean and Standard Deviation of Aspects of Prospective Biology Teachers' Research Skills

Treatment	Aspects of Research											
	Embark and Clarify		Find and Generate		Evaluate and Reflect		Organize and Manage		Analyze and Synthesize		Communicate and Apply	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
SSI with RbL	2.57	0.67	2.41	0.69	3.33	0.86	3.94	1.08	3.39	1.16	4.21	1.18
SSI with GI	2.75	0.69	2.56	0.68	2.35	0.62	2.58	0.95	2.97	1.33	3.17	1.16

Note: Poor (1); Fair (2); Good (3); Excellent (4)

The distribution of prospective biology teachers' Embark and Clarify skills is displayed in Table 5. The research findings showed that Embark and Clarify skills are widely practiced and emerged by prospective biology teachers. These skills are at the prescribed research level. This finding showed that eight prospective biology teachers practiced "determining what knowledge is needed in research before starting the research." This skill appears in both treatment classes (SSI with RbL and SSI with GI). However, different findings were found for other skills. In the SSI with RbL class, prospective biology teachers did not practice the scaffolded and adopted research skills. In the SSI with GI class, prospective biology teachers did not practice open and enlarging research skills.

Regarding "paying attention to and considering ethics, social, culture and team before conducting research," prospective biology teachers practiced this skill in both treatment classes. However, different results were found in mastering open research and enlarging research skills. Prospective biology teachers did not practice these skills in SSI with GI class.

Table 5. Distribution of Prospective Biology Teachers' Embark and Clarify Skills

Description	Treatment	Seven Levels of Student Autonomy for Embark and Clarify						
		Prescribed Research	Bounded Research	Scaffolded Research	Self-initiated Research	Open Research	Adopted Research	Enlarging Research
I determine what knowledge is needed in the research before starting the research	SSI with RbL	++++++++	++++	-	++	+++++	-	++
	SSI with GI	+++++++	+++	++	+	-	+	-
I pay attention and consider ethical, social, cultural and team considerations before conducting research	SSI with RbL	++++++++	++	++	-	++++	+++	++
	SSI with GI	++	+++	++	+++	++	+	+

The distribution of prospective biology teachers' Find and Generate skills is displayed in Table 6. It is shown that SSI in both treatment classes can promote Find and Generate skills at the prescribed and bounded research levels. Seven to eight prospective biology teachers practiced these two levels of ability. Therefore, prospective biology teachers can use facts and data from research and appropriate research methods. There were skills that students did not practice. These skills are scaffolded and adopted research for using facts and data from research. Meanwhile, for using appropriate methods, the skill levels that prospective biology teachers did not practice were open research and enlarging research.

Table 6. Distribution of Prospective Biology Teachers' Find and Generate Skills

Description	Treatment	Seven Levels of Student Autonomy for Find and Generate						
		Prescribed Research	Bounded Research	Scaffolded Research	Self-initiated Research	Open Research	Adopted Research	Enlarging Research
I use facts and data from research	SSI with RbL	++++++++	++++++	-	+	+++	+	++
	SSI with GI	++++++	++	++	-	+++	-	+
I use appropriate research methods	SSI with RbL	++++++	+++++++	+	+++	++	+	+
	SSI with GI	+++++	+++++	+	+	-	++	-

The distribution of prospective biology teachers' Evaluate and Reflect skills is displayed in Table 7. It shows that using SSI with RbL and SSI with GI promotes Evaluate and Reflect skills. These findings also show that prospective biology teachers practiced and developed three skill indicators: (1) determining the level of credibility of the source, information, and data, (2) criticizing the level of credibility of the source, information, and data produced and (3) reflecting on the process metacognitively. The findings indicated that these three skills were high at the prescribed and bounded research levels. The three skill activities were found at scaffolded, self-initiated, open, adopted, and enlarging research levels. However, the opposite results were found for the adopted research and enlarging research levels. Research findings show that these three activities were not found at the adopted and enlarging research levels. These two levels did not appear when prospective biology teachers determined the credibility of sources, information, and data and reflected the process metacognitively.

Table 7. Distribution of Prospective Biology Teachers' Evaluate and Reflect Skills

Description	Treatment	Seven Levels of Student Autonomy of Evaluate and Reflect						
		Prescribed Research	Bounded Research	Scaffolded Research	Self-initiated Research	Open Research	Adopted Research	Enlarging Research
I determine the level of credibility of the sources, information, and data	SSI with RbL	+++	++++	++	++	++++	+++	+++
	SSI with GI	+++++	++++++	+	+	+	-	-
I criticize the level of credibility of the sources, information, and data	SSI with RbL	+++	++++++	+++++	+	+	+++	++
	SSI with GI	++++++++	+++	+	++	-	-	-
I reflect on the processes used metacognitively	SSI with RbL	+++++	++++	++	+	++	+++	++++
	SSI with GI	++	+++++++	+	+	++	-	+

Table 8 shows that using SSI with RbL and SSI with GI promotes Organize and Manage skills. The research results show that the prospective biology teachers highly practiced Organize and Manage activities: (1) organizing information and data, (2) revealing patterns and themes, and (3) managing the research team and process. Research findings also show that prescribed, bounded, and enlarging research are the most widely practiced by students in both research treatments. However, some students did not practice Organize and Manage activities. These results were found at the bounded, open, and adopted research levels, especially in the SSI with GI treatment. The next findings show that Organize and Manage skills in managing the research team and process also did not appear at the open and adopted research levels.

Table 8. Distribution of Prospective Biology Teachers' Organize and Manage Skills

Description	Treatment	Seven Levels of Student Autonomy of Harmonising: Organise and manage						
		Prescribed Research	Bounded Research	Scaf-folded Research	Self-initiated Research	Open Research	Adopted Research	Enlarging Research
I organize information and data	SSI with RbL	+++++	++++	++	+	++	+++	++++
	SSI with GI	+++++++	-	+++	+	-	-	+++
I reveal patterns and themes	SSI with RbL	++++	++++++	+	++++	-	-	++++++
	SSI with GI	+++++	+++	++++	+	-	-	+
I manage the research team and process	SSI with RbL	++	+++++	++	+++	++	+	++++++
	SSI with GI	+++	+++++	++++	+	-	-	+

Table 9 shows five Analyze and Synthesize activities practiced by prospective biology teachers: (1) analyzing information and data, (2) criticizing information and data, (3) synthesizing information and data, (4) producing coherent knowledge, and (5) generating knowledge understanding within the team. Analyzing information and data" was high at the prescribed and bounded research levels. Synthesizing information and data and producing coherent knowledge was high only at the prescribed research level while generating knowledge understanding within the team was high only at the enlarging research level. There were activities that students did not practice, for example, analyzing information and data at the scaffolded, self-initiated, open, adopted, and enlarging research levels.

Table 9. Distribution of Prospective Biology Teachers' Analyze and Synthesize Skills

Description	Seven Levels of Student Autonomy							
	Treatment	Prescribed Research	Bounded Research	Scaf-folded Research	Self-initiated Research	Open Research	Adopted Re-search	Enlarging Research
I analyze information and data	SSI with RbL	++++++	+++++	-	++	++++	_-	++++
	SSI with GI	+++++	++++++	+	-	-	+	+
I criticize information and data	SSI with RbL	+++++	++++++++	+	+++	+	++	+
	SSI with GI	+++	+++	++	++	++	+	+
I synthesize information and data	SSI with RbL	++++++	+++	+	++	++	++	+++++
	SSI with GI	+++++	+++	++++	-	-	++	-

I produce coherent knowledge	SSI with RbL	++++++	+++	+	++	+++	+	+++++
	SSI with GI	+++	++++	+++	+	-	+++	-
I generate knowledge under-standing within the team	SSI with RbL	+++	+++++	-	+++	+++	-	+++++++
	SSI with GI	++++	++	++	-	++	++	++

The distribution of prospective biology teachers' Communicate and Apply skills is displayed in Table 10. The research findings indicate that Communicate and Apply skills have four activities: (1) discussing, listening, writing, and presenting to communicate research results; (2) applying the research results; (3) responding to feedback in discussions; (4) considering ethical, social, cultural, and team issues. The research results show that prospective biology teachers practiced these four activities. The highest activity was found at the level of open research (SSI with RbL), enlarging research (SSI with RbL), prescribed research (SSI with GI), bounded research (SSI with GI), self-initiated research (SSI with GI), and enlarging research (SSI with RbL). The research results show that PBTs did not practice the activities at the adopted and enlarging research levels (SSI with GI).

Table 10. Distribution of Prospective Biology Teachers' Communicate and Apply Skills

Description	Seven Levels of Student Autonomy							
	Treatment	Prescribed Research	Bounded Research	Scaffolded Research	Self-initiated Research	Open Research	Adopted Research	Enlarging Research
I discuss, listen, write, and present to communicate research results.	SSI with RbL	++++	+++++	++	++	++++++	-	++
	SSI with GI	+++	+++++	+	++	-	+	++
I apply the research results	SSI with RbL	++	++++	++++	+++	++	-	++++++
	SSI with GI	++++++	++	++	-	+++	-	+
I respond to feedback in discussions	SSI with RbL	+++	++++++	+++	++++	++	-	+++
	SSI with GI	-	++++	+++	++++++	+	-	-
I consider ethical, social, cultural, and team issues	SSI with RbL	++++	++	+	++	++++	++	++++++
	SSI with GI	++	+	++++	++	++++	+	-

Research findings show that (1) SSI with RbL and SSI with GI promote prospective biology teachers' RSD-7 skills in each level seven levels of student autonomy and (2) There were no differences in prospective biology teachers' RSD-7 skills between the SSI with RbL and SSI with GI treatments.

Student achievement is displayed in Table 11. The mean and standard deviation in the SSI with RbL class are 78.95 and 4.410, and the mean and standard deviation in the SSI with GI class are 79.56 and 6.099. This finding is in line with the previously presented data that the use of SSI with RbL and SSI with GI promotes SL and RSD-7 skills. These findings also indicate no differences in learning outcomes between the two treatment classes.

Table 11. Statistics for Comparison of Prospective Biology Teachers' Achievements

Treatment	N	Mean	Std. Deviation	Std. Error Mean
SSI with RbL	21	78.95*[a]	4.410	.962
SSI with GI	16	79.56*[a]	6.099	1.525

• Mean score is not significantly different from the t-test (P<0.05); Mean score is not different from the Levene's Test (P<0.05)

The results show that SSI with RbL and SSI with GI promote prospective biology teachers' scientific literacy. This finding aligns with previous findings that lectures can implement strategies that include participation activities that promote SL in the classroom, such as discussions, writing articles, and analyzing articles that examine controversial socio-scientific issues. The finding also indicates that students (1) derive relevant knowledge using credible sources, (2) adopt the informant's position, (3) provide valid arguments and opposing arguments based on accurate evidence, (4) analyze arguments and counterarguments, and (5) ask and answer questions to clarify. Thus, this finding shows a connection between the basic components of SL skills (context, competencies, and knowledge) when implementing guided inquiry and research-based learning methods.

The results show that using SSI with RbL and SSI with GI promotes prospective biology teachers' RSD-7 skills, and there is no difference in RSD-7 skills between SSI with RbL and SSI with GI treatments. The findings of this research show that prospective biology teachers practiced many skills at level 1 (prescribed research), level 2 (bounded research), and level 3 (scaffolded research) in both treatment classes. The characteristics of the supervisor level are that there is direction and encouragement from the supervisor. In this research, it appears that prospective biology teachers need direction from lecturers to carry out research. Research findings also show that students are slightly more likely to practice the discipline-leading level, which consists of adopted research (level 6) and enlarging research (level 7). The characteristic of discipline leading is extensive collaboration within the research team. Researchers are combined into research groups that cover the same topic so that each researcher can participate in solving research problems.

Meanwhile, few prospective biology teachers chose level 4 (self-initiated research) and level 5 (open research) in certain sections. These two levels are categorized as researcher-initiated. The characteristic of these two levels is the initiative of prospective biology teachers to conduct research. At this level, students must also initiate research with little support and advice from lecturers.

This study shows no difference in prospective biology teachers' learning outcomes in the two treatment classes: SSI with GI and RbL. These two ways of learning have no different activities and are often used in biology learning. In biology learning, inquiry and research-based learning are chosen to be used due to various factors: authentic (Martineau et al., 2013; Martín-Gámez et al., 2020) and most effective (Hiltunen et al., 2020) to improve the skills and beliefs of students (Kremer et al., 2014). The following research results also supported this finding. Inquiry-based learning is used for learning biology material, such as immunology (Natale et al., 2021; Seixas Mello et al., 2023), molecular biology (Rolfe & Adukwu, 2023), general biology (Snapir et al., 2023), and ecosystem (Smith et al., 2023).

The research findings show that learning theories are applied to the implementation of this research. This research has activities oriented towards human development, adaptation, and change when implementing the GI and RbL learning syntax. This research also shows that learning processes and activities form new knowledge. It is an application of cognitive learning theory and constructivism. These findings show that the steps to examine SSI from scientific articles were then applied in the learning process to promote SL and RSD-7 skills for prospective biology teachers.

The findings of this research also show that the basic framework for using SSI to promote SL and RSD was prepared based on the results of previous research. SSI framework is structured based on design elements, student experience, and teacher attributes, which work together to form variations in learning classes. These three aspects constitute the central situation as fundamental components that form the framework. The classroom environment is a circle representation that will enclose these three components, and peripheral influence is the outer wrapper of the SSI framework. Thus, this research provides several recommendations. SSI in articles can be used as learning materials because it contains global problems that help develop students' literacy. Lecturers can investigate SL and RSD-7 skills using research-based learning and guided inquiry.

CONCLUSION

This research provides several conclusions. *First*, SSI articles can be used as learning materials promoting scientific literacy and RSD-7. *Second*, using SSI with RbL and SSI with GI promotes prospective biology teachers' scientific literacy. The SL components are explaining phenomena scientifically, evaluating and designing inquiry, interpreting data, and knowledge of scientific literacy. *Third*, using SSI with RbL and SSI with GI promotes prospective biology teachers' RSD-7 skills at all levels: (1) Embark and Clarify, (2) Find and Generate, (3) Evaluate and Reflect, (4) Organize and Manage, (5) Analyze and Synthesize, and (6) Communicate and Apply. The seven levels in RSD-7 are prescribed research, bounded research, scaffolded research, self-initiated research, open research, adopted research, and enlarging research. There were no differences in RSD-7 skills between the SSI with RbL and GI treatments. *Fourth*, there is no difference in learning outcomes between the SSI with GI and RbL treatments. To create SL and RSD-7 requires broader learning behavior factors. This study has the limitation of using a relatively short learning time to investigate SL and RSD skills. So, further research is recommended to determine more complex learning behavior factors that can determine SL and RSD-7 skills.

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