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***Secção 1:*** *Investigação em Educação em Ciências, Matemática e Tecnologia*

# *USING ADAPTED PRIMARY LITERATURE TO INTRODUCE STUDENTS TO SOCIOSCIENTIFIC ISSUES: A CASE OF LIGHT POLLUTION AND BIODIVERSITY*

## UTILIZAÇÃO DA LITERATURA PRIMÁRIA ADAPTADA PARA INTRODUZIR AOS ALUNOS QUESTÕES SOCIOCIENTÍFICAS: UM CASO DE POLUIÇÃO LUMINOSA E BIODIVERSIDADE

## USO DE LITERATURA PRIMARIA ADAPTADA PARA INTRODUCIR A LOS ESTUDIANTES A CUESTIONES SOCIOCIENTÍFICAS: UN CASO DE CONTAMINACIÓN LUMÍNICA Y BIODIVERSIDAD

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**ABSTRACT** | Socioscientific issues (SSI) provide a context for understanding scientific information in science education. Science education students learn not only what science is, but also how science is done. Adapted Primary Literature (APL) helps young people read scientific texts critically. Our research aimed to develop lower secondary school students' understanding of SSI through the introduction of APLs. Fifty Slovene students studied three APLs dealing with the effects of light pollution on birds, bats, and moths. The results show that students not only developed higher order thinking skills and scientific knowledge, but also showed further interest and confidence in studying APLs. This confirms that APL use is effective with lower secondary school students when the science articles are well adapted. This is important because it is during these years that students begin to develop their career awareness and become more capable of taking social perspectives and reasoning morally.
**KEYWORDS**: Adapted Primary Literature, lower secondary school students, science education, Socioscientific issues.

**RESUMO** | As questões sociocientíficas (SSI) fornecem contextos para compreender informação científica no âmbito da educação em ciências. Os estudantes aprendem o que é ciência e como esta é produzida. Literatura primária adaptada (APL) facilita a leitura crítica de textos científicos por parte dos jovens. O objetivo da nossa investigação foi estudar o desenvolvimento da compreensão de SSI por parte dos alunos do ensino básico através da introdução de APLs. Cinquenta alunos eslovenos estudaram três APLs que abordavam os efeitos da poluição luminosa em aves, morcegos e traças. Os resultados mostram que os alunos desenvolveram competências de pensamento de ordem superior e conhecimentos científicos e demonstraram maior interesse e confiança para estudar APLs, suportando a eficácia do uso de APLs com alunos do ensino básico. Isto é importante porque é nestas idades que os estudantes começam a desenvolver preferências relativamente à sua carreira e capacidades para adotar perspetivas sociais e raciocinar moralmente.
**PALAVRAS-CHAVE**: Literatura primária adaptada, Alunos do Ensino Básico, Educação em Ciências, Questões sociocientíficas.

**RESUMEN** | Las cuestiones sociocientíficas (SSI) ofrecen contextos para comprender información científica en la educación en ciencias, ayudando a los estudiantes a aprender qué es la ciencia y cómo se produce. La literatura primaria adaptada (APL) facilita la lectura crítica de textos científicos por los jóvenes. Este estudio investigó cómo las SSI se comprenden en la educación básica mediante la introducción de APLs. Cincuenta estudiantes eslovenos estudiaron tres APLs sobre los efectos de la contaminación lumínica en aves, murciélagos y polillas. Los resultados muestran que los estudiantes desarrollaron competencias de pensamiento de orden superior y conocimientos científicos, y demostraron mayor interés y confianza para estudiar APLs, lo que respalda la eficacia del uso de APLs con estudiantes de educación básica. Esto es importante porque es en estas edades cuando los estudiantes comienzan a desarrollar preferencias relacionadas con sus carreras y capacidades para adoptar perspectivas sociales y razonar moralmente.
**PALABRAS CLAVE**: La literatura primaria adaptada, Estudiantes de educación secundaria inferior, Educación en ciencias, Cuestiones sociocientíficas.

## 1. INTRODUCTION

Socioscientific issues (SSI) are a conceptual framework for science education researchers and practitioners, guiding theory, research, and practice to promote scientific literacy (Zeidler, 2014). SSI involve the intentional use of science topics that engage students in dialogue, discussion, and debate. They are often controversial in nature, but also require some degree of moral reasoning or evaluation of ethical concerns when making decisions about potential solutions to these issues. SSI are intended to be personally meaningful and engaging for students, demanding the application of evidence-based reasoning while providing a context for understanding scientific information (Zeidler & Nichols, 2009). Baram-Tsabari and Yarden (2005) emphasise that if we want to educate scientifically literate people, we must teach not only the nature of science (NOS), but also the processes of scientific inquiry. The use of SSI as a means of supporting students' learning about the NOS was one of the earliest focuses of SSI research (Zeidler et al., 2002).

Högström et al. (2024) conducted a systematic review of research on how SSI in science education practice is characterized in studies of teaching and learning from 1997 to 2021. Their findings show that much of the research revolves around the development of students' higher-order thinking skills and scientific content knowledge. Group discussions emerge as the primary teaching method, followed by inquiry where students critically assess information collected from theoretical and/or practical explorations. In this context, inquiry means that students take responsibility for interpreting, reviewing, and evaluating the information they need to be able to think about an issue. Inquiry-based work may include activities where students make observations, conduct interviews or experiments, collect data, or manipulate and process already collected data. The present study aims to contribute to the use of Adapted Primary Literature (APL) in addressing the negative impacts of light pollution on biodiversity, which is an important SSI. While artificial light has improved the quality of human life and is positively associated with security, wealth, and modernity, it has a negative impact on biodiversity (Hölker et al., 2010).

### 1.1 Adapted Primary Literature (APL)

Primary Scientific Literature (PSL) consists of original scientific texts found in journals, technical reports, proceedings, patents, and dissertations (Norris et al. 2009). PSL is written by scientists for scientists. The text genre is argumentative as it contains evidence supported by conclusions. Norris et al. (2009) point out that jargon and technical language are specific to the research field, which can be difficult for non-scientists to understand. Yarden et al. (2001) explain that Adapted Primary Literature (APL) was introduced to help non-scientists understand PSL. Students who study APL develop scientific literacy as they become familiar with the research plan, methodology, objectives, research questions, structure and language of scientific communication, critical evaluation of the conclusions of scientific research, and learn about the entire scientific research process. Since APL is addressing undergraduate (university) and upper secondary school students, its content is adapted to the comprehension level of the target audience (Yarden, 2009). Researchers (e.g., Norris & Phillis, 2003; Yarden, 2009; Brill et al., 2004) argue that there is an increasing gap between science, which is developed and discussed by scientists and is constantly evolving with new research and information, and school science, which is presented as a collection of facts and theories, mainly in the form of a textbook. Understanding contemporary science is crucial, especially when it comes to SSI (Kinslow et al., 2019). APL and textbooks reflect the contrast between real science as understood by science disciplines and the school science taught to students. Osborn (2009) points out that it would be beneficial if young people learned to read scientific texts critically. If they learn about the complexity of scientific research, familiarize themselves with the ambiguity of scientific results, participate in formulating arguments, and express their critical opinions about research, they will be better equipped to interpret various accounts from the world of science (Norris et al., 2009).

Previous research confirms that the use of APL can have a positive impact on students' ability to apply scientific methods, analyse data, link the results obtained to theory, and better understand individual research phases and their significance (e.g., Ariely & Yarden, 2025; Baram-Tsabari & Yarden, 2005). By using APL in the classroom, not only we cover the content objectives of the curriculum, but also objectives related to the NOS (Ariely & Yarden, 2025; Hidayat et al., 2021; Norris et al., 2009; Yarden et al., 2016; Zer-Kavod, 2017). APL also has some disadvantages, as it usually only covers a small part of the learning content (objectives) of the curriculum (Lemus, 2020). Another disadvantage of teaching with APL highlighted in the literature is the lack of knowledge and research skills teachers need when creating learning units (Osborne, 2009; Lemus, 2020; Wilson & Dimitrova, 2022).

### 1.2 Research problem

In addition to scientific concepts and facts, the learning objectives of school science curricula emphasize the NOS, which cannot be effectively achieved through passive, transmissive teaching alone, but is better supported by inquiry-based learning (Newton et al., 2004; Pavlin et al., 2021).

As outlined in the *Primary School Science Syllabus* (2011), modern guidelines for science education in primary and secondary schools in Slovenia emphasize the development of scientific and environmental literacy. The syllabus highlights the importance of helping students understand the role of science in human progress and fostering a positive attitude toward themselves, the environment, and nature. Through inquiry-based learning, students acquire practical scientific knowledge and engage with socio-scientific issues (SSI), which they apply to identify and solve real-world problems. This process supports the development of critical and complex thinking, innovation, and creativity (*Primary School Science Syllabus*, 2011).

Teachers need to explicitly emphasize these aspects in their instruction and should provide opportunities for students to reflect on and explain their ideas, discuss them, and evaluate the consistency of their ideas with those of others (Schwartz & Lederman, 2002). APL has become an explicit approach to science literacy development in schools that mimics scientific inquiry to understand science concepts and how science works in general (e.g., Phillips & Norris, 2009; Seah, 2016; Yarden et al., 2001; Yarden et al., 2016).

### 1.3 Aim and research questions

The research aimed to develop lower secondary school students' understanding of SSI by introducing APL to address the impacts of light pollution on biodiversity. The following research questions (RQ) were addressed:

RQ 1: How does learning with APL affect students' knowledge about the SSI under consideration?

RQ 2: How does learning with APL improve the ability to read and understand scientific literature?

## 2. METHODOLOGY

### 2.1 Participants and data collection procedure

O'Leary (2007) defines action research as a research methodology aimed at facilitating professional or social change. The action research presented in this study was conducted with two seventh-grade classes (students aged 11-12) at a suburban school in central Slovenia. The primary objective was to investigate the efficacy of APL as a pedagogical method for teaching about SSIs. A total of 50 students were invited to participate in the action research.

Prior to the implementation of each APL, students' prior knowledge of the topics—birds, bats, moths, and light pollution—was assessed through pre-tests. The pre-tests consisted of six yes/no questions for each topic (e.g., "Does church lighting affect the number of bat colonies?"). Then, the students carefully read through the APLs, which were 3 pages long (Fig. 1, Appendix) and always contained at least one graph, table or other visual representation. Each APL was accompanied by a short worksheet with questions and tasks to guide the students to read the APL in detail. After each APL implementation, they answered an open-ended question: "Consider how a scientist would explain the effect of light on birds (after the 1st implementation); bats (after the 2nd implementation); moths (after the 3rd implementation)". Students evaluated five statements (Table 3) regarding the APL they had read using a 7-point Likert scale, where responses ranged from 1 (I do not like it at all) to 7 (I like it very much), with intermediate values representing varying degrees of preference (2 - I do not like it, 3 - I do not like it to some extent, 4 - undecided, 5 - I like it to some extent, 6 - I like it). Upon completion of each APL session, students participated in a post-test. During the post-test, they reviewed their responses to the pre-test questions and indicated any modifications or updates to their initial answers.

### 2.2 Adaptation of scientific literature

Yarden et al. (2016, p. 87) describe how primary scientific literature (PSL) can be adapted into adapted primary literature (APL), with modifications applied to specific components of the original article.

- First, the title should capture the student's interest in the article's content. During adaptation, the title may be slightly modified to remove technical terms that students might not understand; however, the core meaning of the original title must be preserved.
- Second, the abstract and keywords must reflect the adapted content of each section of the article. The abstract should include the standard elements—introduction, methods, results, discussion—and appropriate keywords.

- The introduction must also engage the reader's interest. It should clearly define the topic in relation to the research questions or hypotheses. The adaptation should be based on the prior knowledge of the target audience. The introduction typically ends with the research objectives or questions, which should be reformulated to suit the adapted article and the knowledge level of the audience.
- In the methods section of the APL, the methodology should be described in a way that is understandable to students, with technical procedural details omitted.
- The results section should present the main findings. Results that may be too complex or difficult to understand for the target audience can be simplified or omitted. For example, types of graphical representations may be adapted (e.g., Fig. 1).
- The discussion should include only the parts of the original PSL discussion that relate directly to the results included in the APL.
- Finally, a conclusion may be added to highlight the key findings, limitations, and uncertainties.

The process of adapting original research articles into APL is further discussed in Yarden et al. (2010).

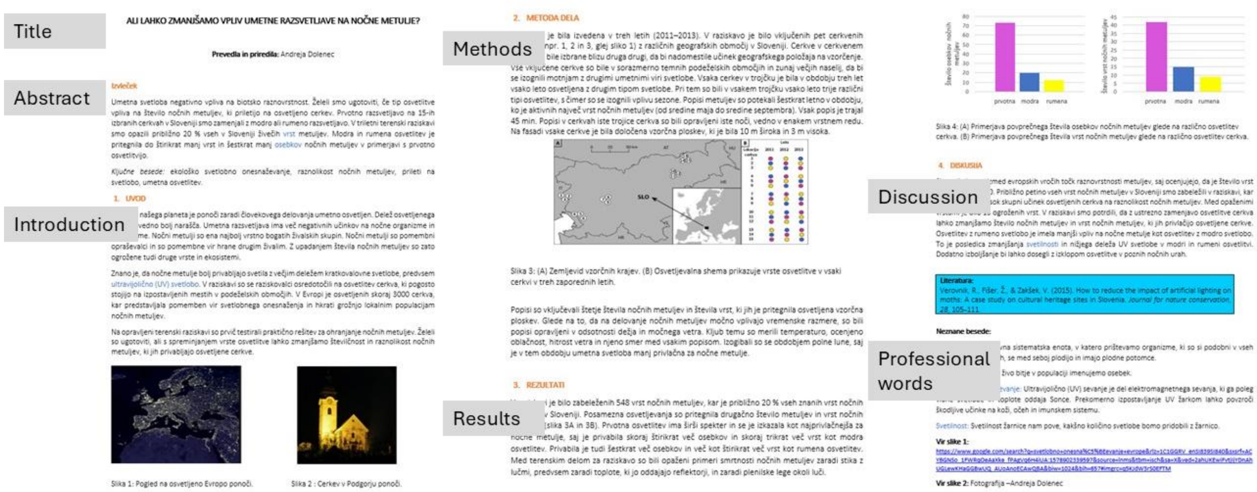



***Figure 1*** Example of an APL entitled "Can we reduce the impact of artificial lighting on moths?" (in Slovene language).

Initially, three relevant scientific articles examining the effects of light pollution on biodiversity were selected (Dominoni, 2017; Rydell et al., 2017; Verovnik et al., 2015). These articles were closely aligned with the learning objectives of the seventh-grade science curriculum. Based on their content, three APL (Adapted Primary Literature) units were developed, each focusing on the impact of light pollution on birds, bats, or moths (see <u>APL examples for light pollution and biodiversity</u>). The APLs were then tested with a separate class of seventh-grade students who were not involved in the action research. To ensure scientific accuracy, all adapted materials were reviewed by a life science expert.

## 2.3 Data analysis

Data entry and analysis were conducted using IBM SPSS Statistics 28 software. Basic descriptive statistics for numerical variables (mean, standard deviation, and frequency) were employed. Due to the non-normal distribution using the Shapiro–Wilk test ($p<0.001$), nonparametric tests were used in the analysis of knowledge tasks. The significant differences in students' knowledge before and after using APL were evaluated using the Wilcoxon test (for paired samples). In addition, effect sizes $r$ were calculated. The qualitative data were analysed using structured content analysis. The Structure of the Observed Learning Outcomes (SOLO) taxonomy, as outlined by Biggs and Collis (2014), was employed to analyze students' responses to the open-ended question. The SOLO taxonomy is a hierarchical framework designed to assess learning outcomes across various subjects and levels, and is applicable to assignments of varying complexity and duration (Biggs & Collis, 2014). The collected data were independently analysed and coded by two Slovenian researchers (95.5% agreement). In rare cases, any discrepancies in coding were resolved through discussion and consensus.

***Table 1-*** *Example of student responses when answering the open-ended question "Think about how a scientist would explain the effect of light on moths?" at the taxonomic levels of the SOLO taxonomy.*

| SOLO taxonomy | Examples of answers |
|---|---|
| 1. Pre-structural Level | *With the help of data and graphs.* |
| 2. Uni-structural Level | *There are fewer moths because of light.* |
| 3. Multi-structural Level | *The impact of light is bad, as it attracts butterflies and reduces their diversity.* |
| 4. Relational Level | *Different types of light have different effects on moths. Lighting with more short-wavelength light attracts moths more. Lighting with less short-wavelength light attracts moths less.* |
| 5. Extended Abstract Level | *Light limits their habitat, living habits and their pollination, which has a very big impact. They are an important source of food for other organisms, which is not possible due to the lack of butterflies.* |

# 3. RESULTS

## 3.1 Students' knowledge of the impact of light pollution on biodiversity

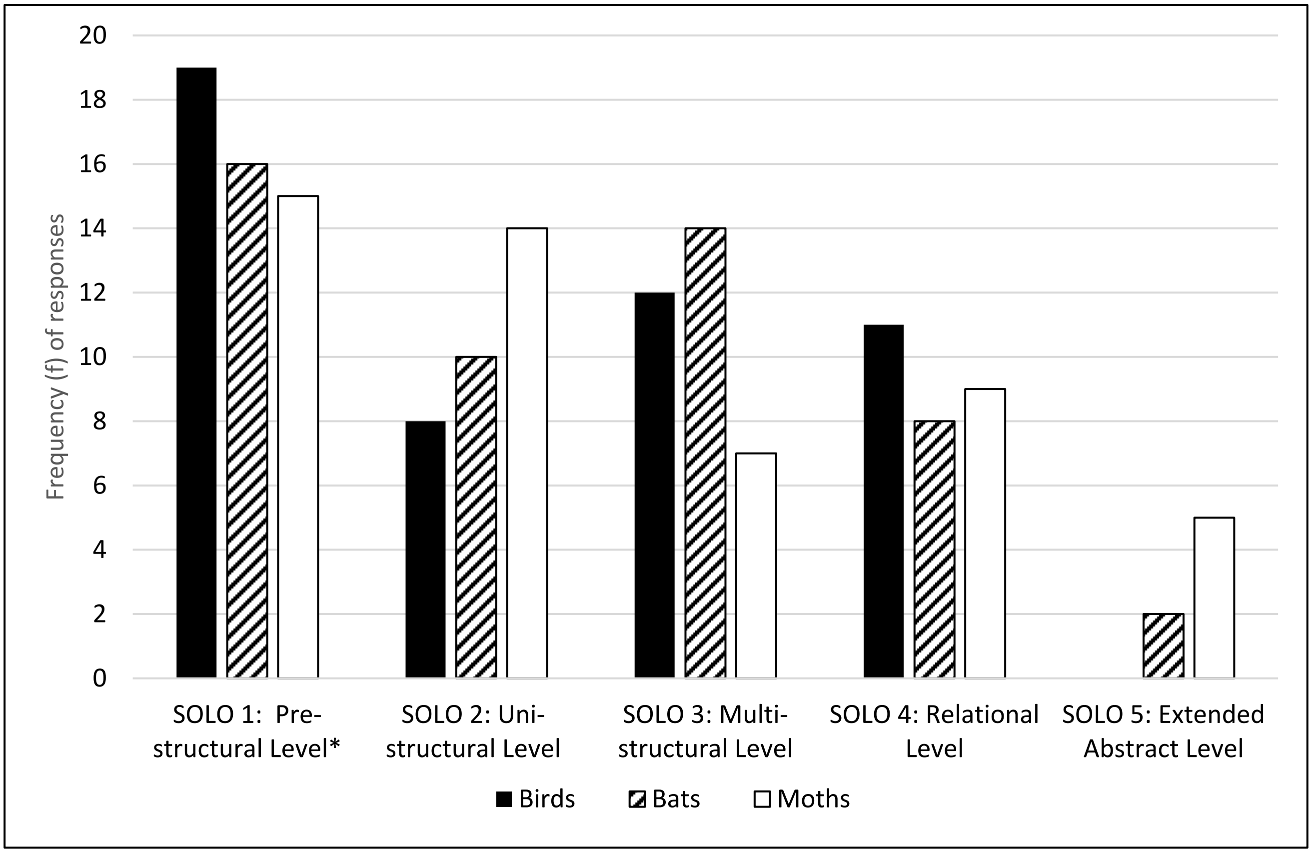
Table 2 show that there are statistically significant differences in students' knowledge about birds before and after the implementation of APL ($Z=-4.571$; $p<0.001$), which deals with birds. The effect size r is moderate (0.46). Students showed better knowledge about birds after the implementation ($M=4.9$; $SD=0.98$) than before the implementation of APL ($M=3.7$; $SD=1.24$). There is also a statistically significant difference in knowledge about bats before and after the implementation of the APL ($Z=-4.980$; $p<0.001$). The effect size r is large (0.50). Students showed better knowledge about bats after the implementation (M=5.1; SD=1.11) than before the implementation of the APL (M=3.8; SD=0.85). There is also a statistically significant difference in the knowledge of moths before and after the implementation of the APL (Z=-2.124; *p*=0.034). The effect size r is small (0.21). Students showed better knowledge about moths after implementation (M=5.6; SD=0.57) than before implementation of the APL (M=5.3; SD=1.05).

***Table 2-*** *Descriptive statistics and Wilcoxon test for knowledge covered by APLs.*

| Knowledge about the effects of light pollution on | *Pre-test* | | *Post-test* | | | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *Z* | $\alpha$ | *r* |
| birds | 3.7 | 1.24 | 4.9 | 0.98 | –4.571 | $< 0.001$ | 0.46 |
| bats | 3.8 | 0.85 | 5.1 | 1.11 | –4.980 | $< 0.001$ | 0.50 |
| moths | 5.3 | 1.05 | 5,6 | 0.57 | –2.124 | 0.034 | 0.21 |

After each implementation of APL, we asked students an open-ended question asking them to think about how a scientist would explain the effects of light on birds/bats/moths. Using the SOLO taxonomy (Biggs & Collis, 2014), the depth of students' knowledge as reflected in their response was analysed (Figure 2). The figure shows that a third of the students remained at the lowest level of the SOLO taxonomy (pre-structural level, SOLO 1). With the exception of one student, these were the ones who had misunderstood the question – in their answers they explained how scientists would present the results of their research, rather than how to scientifically explain the effects of light on birds/bats/moths (e.g., “I might explain this in interactive exercises or show a video”; “I would research first and write the important data in a graph”; “I would first describe how they measured and how they improved things. Then I would explain what results they got and what new things they found.”).

Therefore, in the following section only the remaining four levels of the taxonomy (SOLO 2-5) are described. The results show that 16.0% to 28.0% of students can identify singular aspects of knowledge, while their understanding is limited to isolated disciplinary knowledge (uni-structural level, SOLO 2). For example, a student has recognized the negative impact of light pollution on the number of moth species, but may not understand why this is happening. Between 14.0% and 28.0% of students were able to gather multiple pieces of information but have difficulty linking them coherently (multi-structural level, SOLO 3). For example, one student at this level wrote: "Birds behave differently when they are exposed to light at night. They reproduce 19 days earlier than forest birds and their activity is prolonged." Next, 16.0% to 22.0% of students begin to understand the relationships between facts and their knowledge becomes more complex (relational level, SOLO 4). For example, a student at this level wrote: "The light at night has a bad effect on bats. If it is too strong, they do not go hunting because they are too exposed. Mothers and young animals are particularly at risk because they do not get enough to eat." The final level is SOLO 5, the extended abstract level, in which students not only connect facts, but also extrapolate beyond the given context and formulate hypotheses (0 to 10.0% of students). For example: "Moths are important pollinators and a food source, which is why other species are also endangered. Light affects moths because they are nocturnal and do not fly during the day. Artificial light therefore disturbs them. Spotlights can also kill them with their heat. We can help them by switching off all spotlights in the evening. After the second and third implementation, some students also reached SOLO 5.




*Students misunderstood the question asked - their answers explained ways in which a scientist would present the results of their research and not how to scientifically explain the effects of light on birds, bats or moths.

***Figure 2*** Frequency (f) of responses according to the SOLO taxonomy for students' knowledge of the impacts of light pollution on biodiversity.

### 3.2 Students' views on the use of adapted primary literature in the classroom

Table 3 shows that after each implementation of APLs (M=5.1; M=5.4; M=5.5), students achieved a higher mean value for the statement "I enjoyed reading the article describing the scientific research that was conducted". Students also achieved a higher mean value (M=5.5; M=5.7; M=5.8) for the statement "With the help of the article I read, I now better understand some of the effects of light on organisms" after each implementation.

***Table 3-*** *Descriptive statistics for statements about APL after each implementation.*

| Statements | After the 1st implementation of APL | | After the 2nd implementation of APL | | After the 3rd implementation of APL | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| I enjoyed reading the article describing the scientific research that was conducted. | 5.1 | 1.72 | 5.4 | 1.81 | 5.5 | 1.39 |
| I would also like to read articles written by scientists in class from time to time in the future. | 5.4 | 1.74 | 5.2 | 1.75 | 5.6 | 1.50 |
| Reading the article was very challenging for me. | 3.7 | 1.84 | 3.7 | 1.78 | 3.2 | 1.83 |
| Reading an article written by scientists was a new way for me to learn science and biology in school. | 5.1 | 1.60 | 4.7 | 1.77 | 4.9 | 1.72 |
| With the help of the article I read, I now better understand some of the effects of light on organisms. | 5.5 | 1.39 | 5.7 | 1.34 | 5.8 | 1.27 |

A similar variation in mean values was also observed for the statement “Reading an article written by scientists was a new way for me to learn science and biology at school”. The mean value they reached after the first implementation (M=5.1) decreased after the second implementation (M=4.7) and increased after the third (M=4.9). On average, the students tended to agree more with the statement “Reading the article was very challenging for me” after the first and second implementation (M=3.7) and to a lesser extent after the third implementation (M=3.2). It can be concluded from the results that the students have acquired APL reading skills, which is why they found reading an article less difficult after the third implementation. During the group interviews, students pointed out a comparison between reading an APL and a textbook. They emphasized that what they liked about reading an APL was that other research articles were also presented, that they had all the collected information in one place, that they could read about "the original researcher's work", that they learned the basics of the research method, that the results were described in detail and presented graphically, etc. Some students prefer to learn from the textbook because it is shorter, and the text is supported by many visuals. They were not sure what knowledge is assessed from APLs.

Once the students had familiarized themselves with the structure of the APL, they showed more and more interest in reading it. This is partly confirmed by the responses to the statement "I would also like to read articles written by scientists in class from time to time in the future", where the mean knowledge score decreased after the second implementation and increased after the third. The reason for this fluctuation could lie in the content of the APL itself. From the analyses of the group interviews, it can be concluded that the students want to read new APLs, but with different content (they emphasized other biological articles about the life of other animal species, about different ecosystems, the discovery of new species, and other scientific fields such as history and astronomy).

## 4. DISCUSSION

Reading is a multifaceted cognitive activity that involves complex processes such as comprehension, interpretation, and critical evaluation (Jeon & Yamashita, 2014). It is crucial for students to be exposed to a diverse array of text genres, including scientific texts, during their educational journey (Norris & Phillips, 2008). The first research question of this study sought to examine how learning with APL enhances students' reading comprehension and scientific literacy, particularly in the context of Socio-Scientific Issues (SSI). The findings of this study support previous research indicating that Slovenian lower secondary school students can effectively engage with SSI through the use of APL, consistent with studies conducted with older student populations (e.g., Ariely & Yarden, 2025; Yarden et al., 2016; Yarden, 2009; Zer-Kavod, 2017). These results suggest that APL can be a viable pedagogical tool for studying SSI in lower secondary education. A similar study conducted with seventh-grade students in Indonesia (Hidayat et al., 2021) also affirmed that engaging with, analyzing, and discussing APLs can serve as an effective method for rendering science education more authentic. Yarden (2009) highlights that incorporating APLs in the classroom can significantly improve students' ability to engage with scientific texts, as such texts require readers to accurately extract information, interpret arguments, and critically assess conclusions. Moreover, Ariely and Yarden (2025) demonstrated that exposure to scientific texts presenting opposing viewpoints, coupled with opportunities for critical discourse, enhances students' skills in evaluating information. This is particularly pertinent when dealing with the complex and often argumentative nature of SSI.

The second research question aimed to investigate students' perceptions of how learning through APL enhances their ability to read and comprehend scientific literature. The findings indicate that students expressed high levels of confidence in their learning outcomes following each APL reading. This is consistent with prior research, which has highlighted the positive impact of APL on the development of scientific literacy (Norris et al., 2009; Yarden et al., 2016; Zer-Kavod, 2017). Additionally, students reported that, after becoming familiar with the structure of APLs, their engagement with such texts increased. However, they also stressed the importance of the relevance and appeal of the content, suggesting that students' interest in APLs varies according to individual preferences and career aspirations. This differentiation in student interest aligns with Dillon and Manning's (2010) assertion that instructional design must be closely aligned with knowledge assessment. It is crucial that educators clearly communicate the learning objectives and assessment criteria before students engage with APLs, ensuring that they approach these challenging texts with focus and motivation. This is particularly important, as APLs are among the most demanding texts students will encounter at this stage in their academic development.

The study was conducted with Slovenian students from a single urban school, which may limit the broader applicability of the results. To enhance the generalizability of the findings, future studies could expand the sample to include students from other Slovenian schools or from different countries, enabling comparisons of educational systems and cultural contexts. A notable limitation of the present study is the lack of a follow-up knowledge assessment (e.g., four weeks post-intervention), which could provide further insight into the retention of knowledge over time. Furthermore, additional qualitative data regarding students' conceptual understanding of the SSIs discussed would provide a more nuanced understanding of the research problem and contribute to a deeper interpretation of the findings.

## 5. CONCLUSION AND IMPLICATIONS

The present study provides evidence that Slovenian lower secondary school students are capable of learning about Socio-Scientific Issues (SSI) through the use of Adapted Primary Literature (APL). The majority of students not only demonstrated a solid understanding of the impact of light pollution on biodiversity but also expressed increased interest and confidence in engaging with APLs and scientific texts. The findings suggest that APL is an effective pedagogical tool for fostering higher-order thinking skills and enhancing scientific knowledge related to SSI.

While the majority of previous studies examining the use of APL in science education have focused on upper secondary school and university-level students (e.g., Brill et al., 2004; Ariely & Yarden, 2025), this study extends the applicability of APL to younger learners, provided that the science texts are appropriately adapted. This confirms that APL can be an effective teaching method for younger students when the complexity of the material is tailored to their developmental stage.

Curricula typically define the educational content that schools and teachers are required to teach, and teachers often use these frameworks to guide their instructional practices. As such, a clear alignment between learning objectives and SSI increases the likelihood that these topics will be integrated into lessons. This is exemplified by the inclusion of topics such as light pollution and biodiversity. These findings are particularly significant as it is during the lower secondary school years that students begin to develop greater career awareness and are more capable of adopting social perspectives and engaging in moral reasoning (Steinberg & Cauffman, 1996). Consequently, students at this stage are better equipped to engage with and understand the complexities of SSI within science education.

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