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# PROGRAM FOR INTEGRATING EDUCATION FOR SUSTAINABLE DEVELOPMENT (ESD) INTO PROSPECTIVE BIOLOGY TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK)

**W. Purwianingsih*[1], I. Novidsa[2], R. Riandi[3]**

[1,2,3]Departement of Biology Education, Universitas Pendidikan Indonesia, Indonesia

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## ABSTRACT

This study aims to promote prospective biology teachers' Technological Pedagogical Content Knowledge (TPACK) about Education for Sustainable Development (ESD) or TPACK-ESD through a School Biology Course. The course is an integrated course as it discusses essential biology contents for the school and the strategies to present the content to the students. It is urgent to promote prospective teachers' TPACK-ESD since the existing biology teachers are not prepared to integrate ESD into biology lessons. The study applied a descriptive method based on a seven-step model of Reorient University Curricula to Address Sustainability (RUCAS). Participants in this study were third-year prospective teachers who were taking the course. The effectiveness of this program for prospective biology teachers is drawn from Content Representation (CoRes) and lesson plans prepared by prospective teachers. The results showed that prospective teachers' TPACK-ESD improved from early development to developed level. It means that prospective teachers' TPACK-ESD is still at a low level. Although the program can improve prospective biology teachers' competencies in developing lesson plans, the level is still low. One semester intensive program seems insufficient to promote prospective teachers' TPACK-ESD. Therefore, it is recommended that the program for promoting ESD integration into TPACK-ESD is conducted for an extended time. The novelty of this study lies in the findings and the coverage of the research area. This study is the first to explore a strategy to promote prospective teachers' TPACK-ESD. More studies are needed, especially on teachers' education curriculum and professional development programs, to accelerate the development of teachers' TPACK-ESD.



Keywords: Education for Sustainable Development (ESD); prospective biology teachers; Technological Pedagogical Content Knowledge (TPACK)

## INTRODUCTION

As suggested by UNESCO (2017), Education for Sustainable Development (ESD) is recognized as a strategy to achieve quality education for all and the other Sustainable Development Goals (SDGs). Despite its crucial role, ESD is not yet widely implemented in schools. As teachers are the key persons for implementing ESD (Bürgener & Barth, 2017), improving teachers' competencies should be the first step toward implementing ESD in schools. Indeed teachers may be familiar with environmental education, but ESD is more than just about the environment; it also covers social and economic issues (Hopkins, 2012). ESD is considered education that can help develop students' attitudes, skills, and knowledge to make the right decisions for current and future generations (Anyolo et al., 2018).

Due to the absence of teachers with ESD backgrounds, environment education or ESD is usually taught by science teachers, and most of the competencies are gained through in-service training. Some initiatives were done to educa-

***Correspondence Address**
E-mail: widipurwianingsih@upi.edu

te university students about ESD (e.g. Harpe & Thomas, 2009; Holdsworth & Thomas, 2015; Otte, 2016) but did not focus on how a course may promote teachers' competencies in teaching ESD.

One of the professional knowledge of teachers that needs to be developed is Technological Pedagogical Content Knowledge (TPACK). Groβschedl et al. (2014) stated that teachers' professional knowledge is one of the determinants of the development of students' knowledge. Several research results show that teachers' professional knowledge affects student learning achievement (Förtsch et al., 2016; Liu & Zheng, 2017; Widodo, 2017a; Förtsch et al., 2018). Teachers are expected to carry out an effective learning process through professional knowledge. The professional knowledge of prospective teachers that helps them implement it in classroom learning manifests in Technological Pedagogical Content Knowledge (TPACK).

TPACK was first introduced by Koehler and Mishra (2005). They added technological knowledge to the existing notion of Pedagogical Content Knowledge (PCK) since technological knowledge is a type of essential knowledge for teachers. The addition of technological knowledge as one of teachers' professional knowledge occurs in line with the demands of the times, which tend to lead to mastery of technology. Developing teachers' TPACK starts as early as during preservice education in the college. For this reason, special attention needs to be given to prospective teachers, including prospective biology teachers, to develop TPACK to provide quality education for students in the future.

The success of ESD depends on the attitude and professional knowledge possessed by prospective teachers in providing integrated ESD learning in schools. Teachers' professional knowledge is a measure of success in classroom teaching (Groβschedl et al., 2014). Therefore, it is necessary to develop prospective teachers' professional knowledge by integrating ESD with their TPACK to succeed in students' learning in the future. This professional knowledge can be called TPACK-ESD. ESD integrated learning requires prospective teachers to master biological content knowledge and see its relationship with other concepts in complex situations, such as connecting with environmental, social, and economic issues both on a local, regional, and global scale (Wals & Kieft, 2010; Bertschy et al., 2013; UNESCO, 2017; Bezeljak et al., 2019).

Teachers' understanding of ESD is critical in teaching ESD in class (Handtke et al., 2022). Therefore, prospective teachers must develop good pedagogical content knowledge on ESD (Waltner et al., 2020). There are several ESD competencies that prospective teachers must master to integrate ESD into their lesson plans, including knowledge, systems thinking, attitudes, ethics, and emotions (Mulà & Tilbury, 2009; Cebrián & Junyent, 2015; Okayama University ESD Promotion Center, 2020). The five competencies become one of the benchmark indicators in analyzing the TPACK-ESD for prospective teachers. The development of TPACK-ESD is an important step that must be provided to prospective teachers to prepare their competencies in implementing ESD. ESD integration is critical to prepare the nation's next-generation, ready to face complex challenges in the future (Shumba & Kampamba, 2013). Therefore, providing ESD to prospective teachers is key to integrating ESD. One of the efforts to provide ESD knowledge to prospective teachers is to integrate it into specific courses, especially those that require students to plan lessons.

School Biology is a mandatory course for prospective teachers in the Biology Education Study Program, Universitas Pendidikan Indonesia. This course integrates content knowledge with pedagogical knowledge into PCK (Pedagogical Content Knowledge) and is designed to facilitate students in integrating content knowledge and pedagogical knowledge. Previous studies indicate that teachers struggle to integrate content and pedagogical knowledge into PCK (Purwianingsih & Mardiyah, 2018). Another study reported that teachers failed to describe detailed and specific content in their TPACK (Nasution et al., 2017). Lesson study was one proposed strategy to promote teachers' TPACK (Rochintaniawati et al., 2019).

Students who take this course have taken basic biology courses and biology education courses. Learning in the School Biology course includes deepening the selected contents in the high school curriculum. The chosen topics in the School Biology course include coordination systems, reproductive systems, viruses, and biotechnology, per the inner issues and SDGs 15 Life on Land. The deepening is done by providing the content thoroughly and then relating to how to teach it so that students have PCK abilities (Purwianingsih, 2011).

Several studies have been conducted on developing teachers' TPACK-ESD (e.g., Shumba & Kampamba, 2013). The studies reported a need for a paradigm shift in education for prospective teachers by learning as a connection between

aspects of PCK so that good quality science learning can be created. It is because the PCK idea so far has not been enough to help prospective teachers integrate ESD into learning, so there needs to be a paradigm shift to learning as a connection between PCK aspects (CK, PK, and TK) through the development of ESD TPACK for prospective teachers. Another study was conducted by Brandt et al. (2019) about training prospective teachers' competencies in terms of education for sustainable development (ESD, expected results, and process). The results show that the use of different courses as a vehicle to provide ESD contributes to the development of CK and PCK in prospective teachers. Competency development of prospective teachers is seen as a continuous process throughout the education process in higher education. This study repeatedly shows opportunities for systematic and holistic competency development from aspects of PCK through PCK-ESD lessons of several courses during prospective teachers' education at universities.

A study of prospective teachers' sustainability showed that the mastery of prospective teachers on sustainability competence was still at a moderate level of mastery. There is an influence between the teaching experience obtained with prospective teachers' participation in sustainability projects and the perception of prospective teachers on sustainability competencies (Cebrián & Junyent, 2015; Cebrián et al., 2019; Suhirman et al., 2022). Teaching experience is an essential factor influencing prospective teachers' perception and involvement in sustainability.

A study exploring pedagogical knowledge's roles (Auerbach & Andrews, 2018) showed that pedagogical knowledge is important for the effectiveness of the implementation of active learning. Universities need to explicitly support the development of this pedagogical knowledge of prospective teachers. Pedagogical knowledge is also important because it helps teachers develop other basic knowledge. Thus, pedagogical knowledge facilitates the development of pedagogical content knowledge (PCK) of prospective teachers in higher education. Teaching practices and ESD training experiences for prospective teachers give positive results to prospective teachers' awareness of ESD (Olmos-Gomez et al., 2019). Through a pedagogical approach, lectures using practical applications in the school environment can motivate to develop an awareness of sustainable development in ESD. In addition, learning didactic strategies for implementing ESD in a multicultural context, such as tolerance and empathy, can improve the ability to apply ESD. From this, it can be stated that actual teaching exercises in schools can awaken and develop prospective teachers' abilities in applying ESD in their lesson plans.

A study on the teaching ESD reported that experienced science groups are a "valuable tool" to familiarize students with the complexities related to sustainability issues because it has a scientific complexity that can contribute to accessible related content (Weber et al., 2021). This finding shows that prospective teachers need experienced lecturers to provide ESD awareness and abilities related to sustainability issues. The finding aligns with the results of the previous study (Muller et al., 2020) that suggested alternative pathways to provide opportunities for students to learn about sustainable development without the need to change the curriculum structure of their study program. The proposed model offers a chance to combine education on sustainability with thorough training through a scientific research approach. From this, it can be stated that ESD lesson does not always have to be integrated into the curriculum, but alternative approaches can be used through a course with characters related to ESD. A study in Romania (Dumitru, 2017) showed slightly different results from Muller's research above. The results show that ESD competencies can be implemented and integrated. It can be stated that ESD supplies can be trained either in the curriculum or through an alternative approach by integrating it into a course.

The results of Merritt et al. (2019) research training on ESD or courses for prospective educators are very much needed. Most of these programs are not provided by universities. Meanwhile, Groening & Kelly (2019) argue that education for teachers is the key to implementing ESD in schools. Teachers need to develop ESD-related competencies to implement ESD-integrated learning in schools. For this reason, the ESD program is one of the means so prospective teachers have the necessary professional competencies related to achieving the SDGs. With the program carried out in this research, it is expected to be one of the first steps to introducing and providing ESD knowledge for prospective teachers, especially prospective biology teachers, so it is hoped that after they become teachers, they will integrate this knowledge into their learning in the form of TPACK-ESD.

Based on the background described, this study aims at promoting the development of prospective biology teachers' TPACK on ESD after participating in School Biology. The descriptive method is used with The Reorient University

Curricula to Address Sustainability (RUCAS) Seven-Step Model to support this research. The novelty of this research is to produce a program that facilitates prospective biology teachers in integrating their ESD knowledge and TPACK into TPACK-ESD.

## METHODS

A descriptive qualitative method was employed in the study as it allows a comprehensive and specific summary of a phenomenon based on data on events experienced by individuals or groups of individuals (Lambert & Lambert, 2012). This research was conducted in a School Biology course offered by the Department of Biology Education, Universitas Pendidikan Indonesia. The course is designed to facilitate students' competencies in integrating their content knowledge, pedagogical knowledge, and technological knowledge. The course is individual-based, as participants have to work on different topics.

The study participants were 16 prospective biology teachers in the sixth semester (3rd year). The samples were purposively assigned based on their willingness to participate and commitment. Participants have taken pedagogical courses, e.g., Biology Learning and Learning, Lesson Planning, and Microteaching. Therefore, they are assumed to have sufficient pedagogical knowledge to teach biology. Participants have also taken basic courses on biology, e.g., Physiology, Microbiology, and Genetics (Program Studi Pendidikan Biologi, 2021). The stages of research implementation refer to the Reorient University Curricula to Address Sustainability (The RUCAS Seven-Step Models) with five steps. The steps of research implementation are in Figure 1.

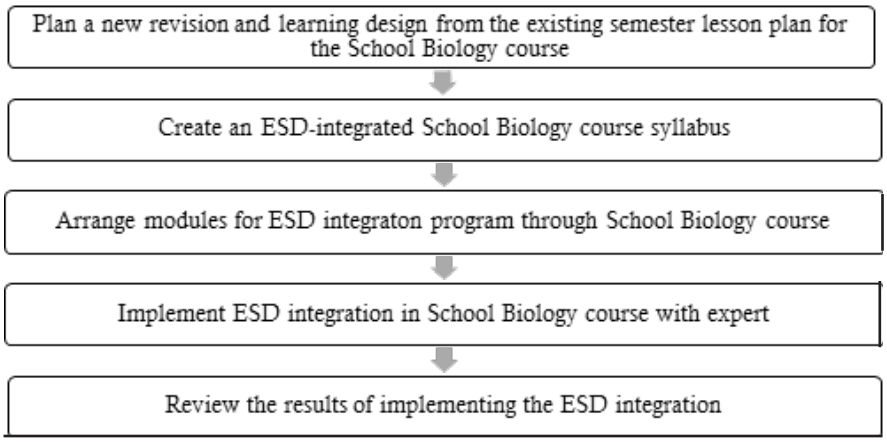


**Figure 1.** The RUCAS Five-Step Model

The TPACK-ESD training program is designed to facilitate the prospective biology teachers to integrate ESD into their TPACK (Fig. 2). In the first step, ESD was introduced by experts. This step aims to provide information about the importance of ESD and ESD competencies that need to be developed. In the second step, the prospective biology teachers participate in a School Biology course designed to help prospective biology teachers to integrate the ESD knowledge into TPACK. In the third step, the prospective biology teachers identified the essential concepts and the best-fit teaching strategies to present the concepts. This step was done by asking the prospective biology teachers to fill in CoRes and designing lesson plans. In the fourth step, the prospective biology teachers present their work for feedback and enrichment from lecturers. Finally, in the fifth step, the prospective biology teachers fill in CoRes and design lesson plans.


**Figure 2.** TPACK-ESD Program

The CoRes framework used in this study was a ten-question TPACK instrument (Widodo, 2017b) to further develop an instrument for assessing pedagogical content knowledge (Loughran et al., 2012). The ESD content was identified based on a framework of ESD essential contents for teachers (Osman et al., 2017). In the final CoRes, four questions were explicitly asked about ESD (Table 1).

The lesson plan refers to the school curriculum (Curriculum 2013) applied in the school. The lesson plans analyzed in this study include lesson plans on contents that can integrate ESD to achieve the third SDG (health and welfare). These materials include coordination systems, reproductive systems, viruses, and biotechnology. The assignment on lesson planning is carried out in a structured way, including initial and final assignments. This final project is the result of improvement from the initial assignment after the program. TPACK-ESD of the prospective biology teachers is identified from their answers to CoRes questions (Novidsa et al., 2021).

**Table 1.** The ESD-Related Questions in the CoRes Questionnaire

| Question Number | Questions |
|---|---|
| 2 | Why is it important for students to understand ESD? |
| 6 | What are factors that influence your consideration for teaching ESD? |
| 8 | What are specific ways of ascertaining students' understanding of ESD? |
| 9 | How will you make use of existing technology to teach ESD? |

The lesson plan is a detailed version of CoRes, so the lesson plans also reflect CoRes. Generally, a lesson consists of learning indicators, learning objectives, content analysis, learning activities, evaluations, learning media, and learning resources. CoRes and lesson plans were scored based on three components, i.e., CK, PK, and TK. The scoring is based on a rubric previously developed (Novidsa, 2020). In the rubric, each response on CoRes and every component of the lesson plans was scored between 0 to 3 (Novidsa et al., 2021). A score of 0 indicates that the prospective teachers do not have good CK, PK, and TK, while a score of 3 indicates that the prospective teachers have developed well-defined and applicable CK, Pk, and TK.

The total scores of prospective teachers' TPACK-ESD obtained from the CoRes & lesson plan were categorized into the five categories (Table 2).

**Table 2.** TPACK-ESD Development Grouping Categories for Prospective Biology Teachers

| TPACK-ESD Scores Improvement (%) | Development Category |
|---|---|
| <21 | Early development |
| 21-40 | Starting to develop |
| 41-60 | Developed |
| 61-80 | Starting to master |
| 81-100 | Mastered |

This category represents the stages of the development of prospective teachers' TPACK-ESD. The first stage of development (early development) represents the first stage during which the prospective teachers master only the basic ideas of teaching ESD. Meanwhile, the highest stage (mastered) represents a mature and complete understanding of strategies to teach ESD.

## RESULTS AND DISCUSSION

As shown in Figure 3, there were improvements in preservice teachers' TPACK-ESD after the program. The final scores were fairly low (50% for CoRes and 42% for lesson plans).

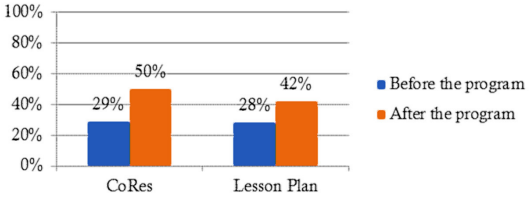


**Figure 3.** Improvement of Cores and Lesson Plan Scores Prior To and After The Program

Figure 3 also shows that the initial CoRes score was in the 'starting to develop' category (29%), and after ESD presentation sessions, the score increased to the 'developed' category (50%), meaning that there was an increase of 21%.

The lesson plan score also increased, from the category of 'starting to develop' (28%) to 'developed' (42%), meaning an increase of 14%. The overall increase for TPACK-ESD is 17%. This figure is obtained from the average increase in CoRes and lesson plan. In more detail, the development of prospective teachers' TPACK-ESD is analyzed from every aspect of TPACK: CK (Content Knowledge), PK (Pedagogical Knowledge), and TK (Technological Knowledge), both

from CoRes and lesson plan. The results of its development are also grouped based on each content studied, i.e., coordination system, reproductive system, viruses, and biotechnology (Table 3).

A more detailed analysis was conducted on each component of TPACK-ESD: CK, PK, and TK. CK assesses prospective biology teachers' knowledge of ESD as an interrelated knowledge of environments, socials, and economics. PK assesses prospective biology teachers' knowledge of all pedagogical factors necessary to be considered in teaching ESD, while TK assesses prospective biology teachers' knowledge of the technology required to teach ESD. Prospective biology teachers' CK, PK, and TK scores are based on their responses to CoRes and the lesson plans. A scoring rubric was developed for assessing CK, PK, and TK. The scores of the rubric are 0 (no significant knowledge), 1 (own very basic knowledge), 2 (own sufficient knowledge), and 3 (own comprehensive and elaborate knowledge).

**Table 3.** Prospective Teachers' TPACK-ESD Scoring Results on CoRes and Lesson Plan

| TPACK-ESD Component | Average Score of Prospective Teachers' TPACK-ESD | | | | | | | | | | | | | | | | (%) | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Content A | | | | Content B | | | | Content C | | | | Content D | | | | | |
| | Prospective Teachers | | | | | | | | | | | | | | | | | |
| | a | b | c | d | e | f | g | h | i | j | k | l | m | n | o | p | | |
| **CoRes and lesson plan before the program** | | | | | | | | | | | | | | | | | | |
| CK ESD | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 2 | 1 | 0 | 1 | 0 | **1** | **0** |
| PK ESD | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | **1** | **0** |
| TK ESD | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 3 | 3 | **2** | **2** |
| **CoRes and lesson plan after the program** | | | | | | | | | | | | | | | | | | |
| CK ESD | 1 | 2 | 1 | 2 | 0 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | **1** | **2** |
| PK ESD | 1 | 2 | 2 | 2 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | **1** | **2** |
| TK ESD | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 3 | **2** | **2** |

*) Content A: Coordination System, Content B: Reproduction System, Content C: Virus, Content D: Biotechnology.
a,b,c,d etc : Name of students.

As presented in Table 3, prospective teachers' CK, PK, and TK prior to the ESD integration program were predominantly 0 (no significant knowledge) and 1 (own basic knowledge). Before the program, prospective biology teachers had very little knowledge of ESD and could not integrate it into TPACK. After the program, there was a slight improvement as the scores were predominantly 2 (own sufficient knowledge). The fact that there was an improvement from the early content (coordination system) to the last content (biotechnology) indicates that the program gradually improved prospective biology teachers' TPACK. Among the three, TK was the component that prospective biology teachers scored the highest. As reported by a previous study (Yulisman et al., 2019), TK was the key component of teachers' TPACK. Therefore, the fact that prospective biology teachers have a strong TK is a good indicator for TPACK.

The data in Table 3 shows that the ESD CoRes and ESD lesson plan prepared by prospective teachers at the beginning of the program are still in the 'starting to develop' category. It shows that prospective teachers can still not plan an integrated ESD learning plan clearly and in a targeted manner. This relatively low acquisition rate indicates that the knowledge of prospective teachers in TPACK is still insufficient to design an integrated ESD learning plan. The development of TPACK-ESD, which is still in its early stages, is in line with the experience and knowledge of prospective teachers. Prospective teachers in this study were sixth-semester students who had experience preparing lesson plans and did not have direct teaching experience in schools. However, the early stages of TPACK-ESD development illustrate that the lesson plans prepared by prospective teachers begin to integrate problems in everyday life related to the concepts being taught, but in general, the lesson plans are only oriented to mastery of knowledge. In the lesson plan, there has been no effort to facilitate students to develop knowledge, attitudes, and skills to solve problems related to problems in everyday life. From the description of answers on CoRes, prospective teachers already know content (Content Knowledge/CK), but their CK does not support integrating ESD into their learning. CK to integrate ESD (CK ESD) should reflect the five ESD

competencies that must be mastered: knowledge, attitudes, actions, scores, ethics, and emotions (Cebrián & Junyent, 2015).

Anwar et al. (2014) stated that the teacher education model needs to be carried out in stages and structured to build experience in teaching in a school. This study's prospective teachers are still beginning to introduce professional knowledge. TPACK is identical knowledge for every teacher to design learning activities that include knowledge related to essential teaching materials and methods and technology suitable for the content to be taught (Riandi et al., 2019). Due to the lack of in-depth knowledge of prospective teachers regarding the content, methods, and technology at the beginning of the program, it is natural that the initial results are still not satisfactory. This inadequate teacher ability needs special attention to be improved (Al-Naqbi & Alshannag, 2018). Therefore, it is necessary to make more efforts to equip prospective teachers about CK and PK integrated with ESD, so that prospective teachers have adequate TPACK-ESD to carry out the real teaching profession in the future.

According to the results of the pre-TPACK-ESD analysis, an advanced ESD program is carried out. The results of the advanced program are in Table 5. Based on this, it can be stated that, in general, there is an increase in prospective teachers' ability to develop TPACK-ESD in all its aspects (CK, PK & TK), both based on the CoRes score and the lesson plan score for all the content studied. After the ESD program, the ESD integration appears to have undergone a development identified as being in the 'developed' category. This is evidenced by the analysis results on CoRes and lesson plan, which showed that ESD integration was more transparent and focused after the advanced ESD program than the initial task. Table 3 shows that the average score of each prospective biology teacher tends to increase. Based on the average gain, it can be said that the integration of ESD in the lesson plan is still general. However, this only happened to a few prospective teachers who had not yet experienced the development of TPACK-ESD. The development of TPACK-ESD is more clearly seen in the model number (Mo). The mode number indicates an increase in the CK ESD and PK ESD aspects. The increase in the number of modes indicates that prospective teachers experience more knowledge development to integrate ESD into the lesson plans after the ESD program.

Although the CoRes & lesson plan analysis results in the final project have increased, the core CoRes design has not shown ESD integration, especially in the Pedagogical Knowledge (PK). Thus, it is necessary to develop PK that facilitates teachers in designing ESD learning through a new approach (Wals & Kieft, 2010; UNECE, 2012; Bertschy et al., 2013; Anyolo et al., 2018; Büssing et al., 2019). A new approach or way of learning ESD aims to facilitate learning related to issues in people's lives at various levels, covering social issues at local, regional, and global levels that are future-oriented (Wals & Kieft, 2010; UNECE, 2012; Bertschy et al., 2013; Bezeljak et al., 2019). Therefore, learning or the ESD approach must be carried out using an inter-multi-disciplinary and holistic approach so that prospective teachers are trained in developing the competencies that must be mastered to realize ESD (Winter & Cotton, 2012; Exter et al., 2013; Anyolo et al., 2018; Büssing et al., 2019). This effort can be made by familiarizing ESD-integrated learning to prospective teachers.

The CoRes and lesson pan analysis results also illustrate that the dominant ESD TPACK component is the CK ESD aspect. CK ESD requires prospective teachers to be able to master content that is integrated with other fields of knowledge so that it will make it easier for prospective teachers to integrate ESD (Bertschy et al., 2013; Al-Naqbi & Alshannag, 2018; Brandt et al., 2019; Merritt et al., 2019). When a prospective teacher already has adequate CK for ESD, it will be easy for prospective teachers to determine the learning activities and technology to be used, in this case regarding PK and TK. Prospective teachers in this study still have inadequate CK to integrate ESD, so ESD is not visible in the lesson plans they design.

The complexity of ESD learning requires the ability of teachers or prospective teachers to construct their professional competencies (Fadeeva & Mochizuki, 2010). This can be done by reflecting on the teacher's learning process and networking (Comenius 2.1 Project, 2008). ESD. Thus, a program with a pedagogy and competency approach can be the key in providing ESD to prospective teachers, according to Lozano et al. (2017).

Based on the research results, there has been a development of TPACK-ESD in prospective teachers through an integrated program in a course. However, the increase has not yet reached the maximum result. Several things can cause this. Based on the initial knowledge data, it is known that the knowledge of prospective teachers about ESD is still low. Prospective teachers tend to master knowledge competencies in ESD, while other competencies (attitudes, ac-

tions, values & ethics, and emotions) tend not to be mastered by prospective teachers. The lack of mastery of prospective teachers on ESD competencies causes the development of TPACK ESD for prospective teachers to be hampered. In addition, the thing that underlies the lack of development of TPACK-ESD prospective teachers is that prospective teachers do not have actual teaching experience. For this reason, we need an advanced program that can provide other competencies still lacking, such as attitudes, actions, values & ethics, and providing teaching experience in the field, for example, through teaching internship, in addition to strengthening PK and TK abilities. Prospective teachers are ready to carry out the teaching profession in the future.

## CONCLUSION

The results of this study show that a course specifically designed to promote the integration of TPACK and ESD could improve prospective biology teachers' TPACK-ESD. Most participants improve from 'starting to develop' to 'developing.' This study also finds that TK is the TPACK component that prospective biology teachers score the highest. It does not mean that CK and PK are unimportant, as CK, PK, and TK are interrelated knowledge. Due to the interrelated nature of CK, PK and TK, it is recommended that efforts to promote prospective teachers' TPACK-ESD should be conducted in an integrated and comprehensive way. It is recommended that the programs should provide opportunities for prospective teachers to integrate their content, pedagogy, and technological knowledge, such as by designing lesson plans. This study acknowledges limitations to the study, such as a limited number of participants and a single course. It is recommended that future research involve more participants, and the program is conducted in several courses that offer pedagogy, content, and technology. A multi-course program should help prospective teachers integrate the knowledge in TPACK-ESD.

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