Technological pedagogical content knowledge (TPACK) prospective biology teacher in integrating education for sustainable development (ESD) in their learning planning

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Abstract. Education to realize Sustainable Development Goals (SDGs) is known as Education for Sustainable Development (ESD). Teachers with adequate TPACK competencies integrated ESD is one of the keys to realizing ESD. The purpose of this paper is to reveal the professional knowledge of prospective biology teachers in the form TPACK-ESD, in designing learning plans before and after got ESD briefing. TPACK-ESD assessed from CoRes and RPP integrated ESD. Eight prospective teachers in the third year who were taking the capita selecta biology course were used as the research sample, chosen by convenience sampling. Descriptive research was used to study TPACK-ESD prospective teachers by collected data consist of CoRes and RPP about viruses and biotechnology. Scoring results of CoRes and RPP that analyzed through descriptive statistics, showed that TPACK-ESD prospective teachers tended to increase after the ESD briefing for both contents. For each component of TPACK, the results showed that content knowledge (CK) illustrating knowledge integrated ESD compared before ESD briefing. Pedagogical knowledge (PK) has shown a learning design that can facilitate students to be able to develop ESD competencies compared before ESD briefing. On the other hand, Technological knowledge (TK) prospective teachers did not seem to increase after ESD briefing.

1. Introduction
Education is one of the efforts to achieve Sustainable Development Goals (SDGs) is known as Education for Sustainable Development (ESD). Teachers with adequate TPACK competencies integrated ESD is one of the keys to realizing ESD. Education to realize SDGs is known as Education for Sustainable Development (ESD) \cite{1,2}. ESD facilitates students in developing attitudes, skills, and knowledge related to social, economic, and environmental life \cite{3}. Through ESD it is expected that human life can be achieving sustainability, which is better life amid the limitations of nature by maintaining the balance of life in social, economic, and environmental dimensions \cite{4}.

Through ESD it is also hoped to be able to create a peaceful community life, following the main objectives of the SDGs \cite{2}. This can happen if students have been equipped with the mindset and attitude that leads to consideration of present and future life \cite{5}. Schools have an important role in realizing ESD, this can be done by integrating learning with the principles of sustainable development \cite{6}. The integration of ESD in learning requires knowledge of complex content and contains an
attitude component that is consistent with the principles of sustainable development [7]. Therefore teachers must have the professional knowledge to implement ESD in their learning.

Teacher professional knowledge is one of the factors of learning success [8]. Professional knowledge that must be considered to realize ESD is knowledge to design learning plans [9]. The results of Shumba & Kampamba research [10] state that Pedagogical Content Knowledge (PCK) is not enough to help teachers integrate ESD in learning, so it is necessary to develop professional knowledge that integrates ESD into PCK, that is PCK-ESD. In addition to professional knowledge, ICT is also one of the things that facilitate the integration of ESD [1]. Therefore, this research is given special attention to the development TPACK of prospective teachers in realizing ESD. TPACK is an identical knowledge in each teacher to design learning activities that include knowledge related to teaching materials, as well as methods and technologies that are appropriate to the material to be taught [11]. In this study, specifically, the TPACK analyzed was how a prospective teacher learning planned that integrated ESD, then this was called TPACK-ESD.

One way to develop TPACK-ESD to prospective teachers is through providing ESD briefing in a certain subject. One of the courses that can be integrated with ESD is a course that facilitates prospective teachers in developing their professional knowledge through an assignment in designing learning plans. Through these courses, it is expected that prospective teachers can design learning in which to integrate ESD (TPACK-ESD). The briefing activity that ends with the assignment can be applied in the Capita Selekta Biology course [12]. The Kapita Selekta biology course is one of the compulsory subjects for prospective teachers in the Department of Biology, Indonesian University of Education.

Learning in the capita selekta biology course covers the deepening of selected material contained in the high school curriculum. The deepening is done by mastering the material thoroughly so that prospective teacher students can connect one concept with other concepts comprehensively [12]. Selected material in the capita selekta courses includes Viruses & Monera, Biology Cell, Excretion & Circulatory Systems, Coordination & Reproductive Systems, Metabolism, Heredity, and Biotechnology. Some of the material is relevant to the issues in the SDGs, that is the 3rd of SDGs Good Health and well-being, including the reproductive system, coordination system, and viruses and the 15th of SDGs, Life on Land which includes heredity [2].

Through Capita Selekta biology lectures that are preceded by ESD briefing, it is hoped that the TPACK-ESD description of prospective biology teachers could be obtained. This is important to do to prepare competent teacher candidates in realizing ESD. Besides that, it is expected to explore what factors can help prospective teachers in developing TPACK-ESD in planning biological learning.

2. Methods
This research is a descriptive study to analyze in-depth and explain the ability of TPACK-ESD of prospective biology teachers based on facts found in the field. The data will be collected about the TPACK-ESD of prospective biology teachers through the ESD briefing program that is integrated into the capita selekta biology course. The sample was third-year prospective teacher students who were taking the capita selekta biology course, consisted of eight prospective biology teachers who were assigned assignments about designed learning plans of virus and biotechnology contents. A convenience sampling technique was used in the research. The selection of 2 samples of these contents was done because both of these contents are following the current hot issue that is currently the Covid-19 pandemic problem which is one form of events that are in the socio-cultural dimension [1].

Through the results of assignments in the course, analyzed whether there is the integration of ESD in the design of learning plans for virus and biotechnology contents related to health in the community environment. Data collection was carried out during the capita selecta lecture process (February-May) academic year 2020/2021 by analyzed Content Representation (CoRes) adapted from Widodo (2017) [13] which is the result of development from from Loughran et al., [14] and the Learning Plan (RPP) and the lecture process. The TPACK-ESD analysis is carried out based on the rubric of the CoRes assessment and ESD integrated RPP which is compiled based on ESD principles. Henceforth, in-depth
descriptive analysis carried out by triangulated data to obtain a TPACK-ESD description of prospective biology teachers. The flow of research is illustrated in the following Chart.

![Research Flow Chart](chart.png)

Note: *outside lecture hours

**Figure 1.** The flow of research implementation

### 3. Result and Discussion

The research only focused on discussing the integration of ESD in learning plans about viruses and biotechnology. Eight prospective teachers get the task to make a learning plan of virus and biotechnology, they are AF, FHA, HZ, RM, RNA, DNA, RAP, and YS. Before taking the capita selekta biology course, each prospective teacher has fulfilled the prerequisite courses related to biology learning planning.

#### 3.1 Content Representation (CoRes)

TPACK-ESD of prospective biology teachers is identified from the teacher's answers to several CoRes questions. The questions were selected based on their ability to access prospective teacher knowledge about ESD integration based on the ESD framework developed by Osman et al.,[3]. Based on the results of the analysis of the ESD framework [3], there are four CoRes questions analyzed in this study, the list of questions can be seen in Table 1.

**Table 1.** List of CoRes questions analyzed based on the ESD framework Osman et al., (2017)

| Question to | Question |
|-------------|----------|
| 2 | Why it is important for student to know this? |
| 6 | Other factors that influence your teaching of this idea? |
| 8 | Specific ways of ascertaining student’ understanding or confusion around this idea |
| 9 | How will you make use of existing technology in learning this idea? |

Some of the CoRes questions above can assess the knowledge of prospective teachers in integrating ESD into their learning design. CoRes assessment is carried out twice, which is initial CoRes and improvement CoRes to see the development of TPACK-ESD prospective teachers during ESD briefing. Data on CoRes score for prospective teachers are listed in Table 2.
The CK was important to the learning process. The integration of ESD in learning has increased for all prospective teachers. It is necessary to assess students' ESD competencies in addition to their content knowledge (CK). CK is knowledge about learning strategies, how to teach, the psychological condition of students and students' initial knowledge [16].

The answer to question number 6 about the factors considered in learning has increased for all prospective teachers on CoRes after re-briefing about ESD. This can be seen from the answers of prospective teachers in each question. Scoring is done in the range 0-3, but there are no prospective teachers who can get a score of 3 for each answer.

Before the briefing, the ESD framework that appeared in the answers of prospective teachers was still general. After carrying out further debriefing to emphasize important parts based on the results of the initial assignment it can be seen there is an improvement. From the results of the improvement of the CoRes was 32%, this indicated an increase after being re-briefing about ESD with an average acquisition of 59%. Table 2 showed that there is an increase in each score of the answers to question number 8 it should contain an assessment of whether students have understood learning or not. Some prospective teachers have not been able to formulate it, they are FHA and RM, who both get a score of 0 both in the initial assignment or after re-briefing. Based on the ESD framework [3] in answer number 8 it should contain an assessment to assess students' ESD competencies in addition to understanding the complex content that is multidisciplinary in science. For this reason, the ability of teachers to plan integrated ESD evaluations for students has not been mastered by all teacher candidates. The answers to questions 6 and 8 can describe the prospective teacher's pedagogical knowledge (PK). PK is knowledge about learning strategies, how to teach, the psychological condition of students and students' initial knowledge [16].
PK expected in this research is PK in integrating ESD. Based on the results of the prospective teachers’ answers on the initial CoRes and the improvements listed in Table 2, it can be seen that there tends to be an increase in PK-related teacher candidates in integrating ESD. Furthermore, the knowledge of prospective teachers about technology or Technological Knowledge (TK) can be analyzed from CoRes answer number 9 about the use of technology in learning. Based on the scoring data in Table 3, it can be seen that the TK of prospective teachers is less likely to experience an improvement in the task of improvement.

3.2 Learning Design (RPP)
Apart from CoRes, TPACK-ESD of prospective teachers also were analyzed from the RPP made by prospective teachers. RPP is a development of CoRes so that the learning plan is more clearly detailed. In RPP one concept in the CoRes was chosen and then was developed into a lesson plan (RPP). The RPP format in this research follows the RPP format in the 2013 Curriculum. There are several RPP components analyzed in this study to see the integration of ESD. These components sequentially include indicators, learning objectives, material analysis, the activity of learning, evaluation, learning media, and learning resources. The scoring of each component of the RPP is given in the range 0-3. The results of the prospective teacher's lesson plan are listed in Table 3.

Table 3. The scoring at learning design integrated ESD before and after briefing

| Prospective Teacher | Before briefing Component | Final score (%) | After briefing Component | Final score (%) |
|---------------------|---------------------------|-----------------|--------------------------|-----------------|
| AF                  | 1 2 3 4 5 6 7             | 33              | 1 2 3 4 5 6 7            | 52              |
| FHA                 | 1 1 1 1 0 2 2             | 38              | 1 1 1 1 2 1 2 2          | 47              |
| HZ                  | 2 2 2 0 2 2 2             | 57              | 2 2 2 2 2 2 2 0          | 67              |
| RM                  | 2 2 2 1 2 2 0             | 52              | 2 2 2 2 2 2 2 0          | 52              |
| ARN                 | 0 0 0 0 0 0 3 2           | 23              | 1 1 0 0 0 3 2            | 33              |
| DNA                 | 0 0 0 0 0 0 3 2           | 23              | 0 0 0 0 0 3 2            | 23              |
| RAP                 | 0 0 1 0 0 3 2             | 28              | 2 2 1 1 0 3 2            | 52              |
| YS                  | 0 0 0 0 0 0 3 2           | 23              | 0 0 0 0 0 1 3 2          | 28              |
| Means               | 1 1 1 0 1 3 2             | 35              | 1 1 1 1 1 3 2            | 44              |

Note: (1) Indicator of Learning, (2) Learning Objectives, (3) Analyzed of Content, (4) Activity of Learning, (5) Assessment, (6) Media of Learning, (7) Learning references

Based on the data in table 3 showed that there has been an improvement in the RPP ESD compared initial task, although its development is not too far away. Table 3 showed the average final score of prospective teachers in the initial RPP is 35% and the final RPP after improvement is 44%. In Table 3 it can be seen if all prospective teachers have increased final scores on assignments after debriefing ESD.

CK of prospective teachers can be analyzed from the formulation of indicators, learning objectives, and material analysis in the lesson plan. In the eight lesson plans of prospective teachers, it can be seen prospective teachers are still not able to formulate indicators, learning objectives, and viruses or biotechnology learning materials that are integrated with ESD as a whole. Only one or several of the ESD integrated indicators, objectives, and material. At the beginning of the integration, the integration was still general, but after the re-briefing about ESD integration, it was clearer although only a few appeared. This indicated that the CK of prospective teachers experiences development after ESD re-briefing for assignments repairs.

However, what is highlighted in the RPP is PK of prospective teachers that have not been able to design a learning activity design that illustrates that learning is integrated ESD both on viruses or biotechnology. Generally, ESD is only illustrated by collaborative activities and efforts to facilitate students to develop problem-solving abilities related to real problems that are happening in the
environment related to viruses or biotechnology. On virus material, the spread of the COVID 19 virus is used as a topic in learning. Furthermore, biotechnology material raised issues about recombinant DNA in the health sector. Learning that facilitates students to recognize and analyze problems in the real world is one of the learnings which is expected in ESD [17]. While the series of other activities on learning activities still look like ordinary learning.

From the above explanation, it can be seen the RPP-ESD of prospective teachers from the initial assignment to improvement has increased. Improvements mainly occurred in the formulation of indicators, learning objectives, and core activities as shown in Table 4. Even so, the existing RPP-ESD still does not show the integration of ESD following the ESD framework, especially in the learning activities. Based on this fact, it is necessary to emphasize the development of CK ESD and PK ESD of prospective teachers as professional competences in ESD. Because CK and PK play an important role in realizing ESD [6, 18].

In addition to CK and PK, TK of prospective teachers is also important to build TPACK-ESD. Judged from the CoRes and RPP, prospective teachers have involved technology in learning. However, the use of technology is only limited to the media for delivering messages to teachers, not the media for students to develop ESD competencies. This shows if the TK of prospective teachers is at the lowest indicator based on the TK indicator proposed by Yulisman [19]. Although, the aim of making the material easily accessible to students is one form of ESD realization [1]. Based on this it can be said that TK of prospective teachers in designing virus and biotechnology learning activities is at an early stage, this will develop along with the experience and technology training received by prospective teachers [20]. Based on that data improvement of TK prospective teachers is an important thing to do, because TK in teaching helps prospective teachers to transform students’ mindset in understanding a material content [20].

Based on the data of CoRes and RPP that has been described above, it showed that the development of ESD CoRes to become an ESD RPP cannot be done optimally by prospective biology teachers. Learning activities still look like ordinary learning, although some material and learning objectives have been linked to health issues in the community. This proves that the PK of prospective teachers is still less good than CK in integrating ESD into learning. Yulisman's research results [19] revealed that CK was more dominant in teacher TPACK due to several factors, including because teachers assumed that by mastering CK, learning would be more natural and CK mastery would facilitate the development of other TPACK components, namely PK and TK.

The ability of teachers who are still inadequate needs to get special attention to be improved [21]. Therefore, the need for more efforts to equip prospective teachers about CK and PK integrated with ESD. To integrate ESD into learning, prospective teachers must have knowledge related to natural, social, and human knowledge. Mastery of all three knowledge can be helping prospective teachers to understand ESD [22]. Also, it is necessary to have a PK that facilitates teachers in designing ESD learning, through new approaches [1, 6, 5, 7, 23]. A new approach or way of learning ESD aims to facilitate learning related issues in social life. These issues include social issues at the local, regional, and global levels which are future-oriented [1, 6, 23, 24]. Therefore, ESD learning must be done using an approach inter-multi-disciplinary and holistic [5, 7, 20, 25, 26].

4. Conclusion
From the results known that ESD briefing influences the development of the ability of prospective teachers to design integrated learning ESD. CoRes analysis results showed that the TPACK ESD for prospective biology teachers has increased in the initial assignment improvement after gaining further emphasis on integrating ESD in learning. Apart from CoRes, TPACK ESD also analyzed from the RPP. Similar to CoRes, the RPP for prospective teachers has increased after ESD re-briefing. The component of TPACK that has increased after ESD re-briefing is CK and PK, on the other hand, TK did not seem to have increased after ESD re-briefing. Although CK prospective biology teacher has shown multidisciplinary
knowledge by connecting material with real problems in the world related to diseases caused by viruses, so does on biotechnology contents.

5. References

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