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Research-Based Biotechnology Book with Virtual Laboratory for Elevating TPACK of Biology Pre-Service Teacher

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Abstract. This study aims to determine the development of Technological Pedagogical and Content Knowledge (TPACK) biology education pre-service teachers using research-based biotechnology book equipped with a virtual laboratory. This research was conducted at the Biology Education Program-University of Jember, which involved 32 pre-service teachers who took the biotechnology course. This research applied Reflective, Recursive, Design, and Development (R2D2) design model and *paired sample t-test* to figure out differences between before and after using the developed product. The validation process involved six experts of content, media development, and user. The results of the book and virtual laboratory validation showed an average value of 86.17%, which is classified as a very valid category. The pre-service teacher response revealed an excellent value of 80.58%. Subsequently, a biotechnology book and virtual laboratory were used to test the TPACK competencies level of biology pre-service teachers. The *paired sample t-test results* showed 0,000 values, which means there were significant differences before and after the use of the research-based book and virtual laboratory developed. To summarize, a research-based biotechnology book equipped with a virtual laboratory can increase TPACK of biology pre-service teachers and recommend them as tools to teach biotechnology.

Keywords: Technological knowledge; Content Knowledge; Biotechnology; Virtual laboratory; Pre-service teacher.

1. Introduction

The rapid development of biotechnology is followed by increasing research in the field of biotechnology to produce biotechnology products. Recently, biotechnology products have invited pros and cons regarding the positive and negative impacts they have caused. A proper understanding of the biotechnology concept is one way to anticipate the effect (Bal, Samanci, & Bozkurt, 2007). The ability to understand the concept of biotechnology must be part of the element for providing the pre-service teachers as the next generation and members of the community, which is a critical component to control and follow the development of the science. The teacher has a crucial role in this matter. Biotechnology is a multidisciplinary and applied science and is one of the most challenging technology fields to teach (Moreland, Jones, & Cowie, 2006).

Based on several studies, mastery of the concept of biotechnology for both pre-service teachers and the general public is currently still low, which influences their acceptance of this kind of technology. This condition happens very likely due to the lack of teachers' ability to teach biotechnology (Bal et al., 2007; Roothaar et al., 2006; Dyehouse et al., 2008). Teachers as one of the essential elements which will be responsible for teaching biotechnology materials correctly and adequately need to be equipped with mastery of strong basic concepts as well as the ability to teach concepts (pedagogy) accurately and appropriately by using technology in the learning (Moreland et al., 2006). So that prospective teachers must have *adequate capabilities on Technological Pedagogical and Content Knowledge* (TPACK) of biotechnology (Kohler & Mishra, 2006).

Biotechnology courses have been established for years for biology pre-service teacher teachers. However, pre-service teachers have no experience in laboratory work related to molecular biotechnology techniques due to the lack of laboratory facilities. Consequently, pre-service teachers have incomplete mastery of the biotechnology concept. One effort to tackle that problem is to conduct research-based learning. Implementation of biotechnology research results in learning can be applied through a research-based book. The book containing research results from biotechnology lecturers will provide information on the latest developments in biotechnology for pre-service teachers and are expected to help pre-service teachers understand ideas, concepts, and theories in the field of biotechnology (Widayati et al., 2010). Regarding the lack of biotechnology laboratory facilities, the book can be supplemented with interactive learning media in the form of virtual laboratories. Based on this condition, this study is needed to determine the effect of research-based biotechnology textbooks equipped with virtual laboratories on TPACK of biology education pre-service teachers.

A short description of Research-based Learning (RBL), biotechnology book and virtual laboratory, as well as Technological Pedagogical and Content Knowledge (TPACK), will be presented to construct preliminary insight.

1.1 Research-Based Learning (RBL)

RBL is one of the learning approaches that are student-oriented learning and integrated research in the learning process. RBL is multifaceted, which refers to various learning methods. RBL provides opportunities for pre-service teachers to experience for information gathering, hypotheses composing, data collecting, data analyzing, and making conclusions based on data provided (Widayati et al., 2010).

There are several strategies in applying RBL. The following are some strategies for integrating empirical learning and research developed at Griffith University, namely: (1) Enriching teaching materials with the results of lecturers' research, (2) Adopting the latest research findings and tracking its developments timeline, (3) Enriching learning activities with up to date research issues, (4) Teaching research methodology in the learning process, (5) Enriching the learning process with small-scale research activities, (6) Enriching the learning process by involving pre-service teachers in institutional research activities, and (7) Enriching the learning process by encouraging pre-service teachers to sense the research culture in the faculty or department, and (8) Enriching the learning process with values that must be possessed by researchers (Griffith Institute for Higher Education, 2008).

RBL is an authentic problem-solving teaching and learning system with emphasizing problem formulation, problem-solving, and communicating the benefits of the research result. That is believed to be able to improve the quality of learning. It has a method of cooperative learning, problem-solving, authentic learning, contextual, inquiry, and discovery model in constructivism (Widayatiet al., 2010). This research-based learning approach can change the habit of students in the learning process from memorizing concepts and facts into learning based inquiry. Thus, the students must try to answer the problem by understanding first and then solving a problem.

This kind of learning model is based on constructivism philosophy that consists of four aspects, namely: the learning by developing student's understanding, prior knowledge, social interaction process, and meaningful learning through the real experience. Research is a valuable tool to improve learning quality. The research component consists of background, procedure, implementation, research results, and discussion, as well as the publication of research results. All of them provide crucial meaning that can be seen from a few viewpoints, among others: formulate problems, solve problems, and communicate the benefits of research results. Consequently, it is reliable to elevate the quality of learning (Roach et al., 2000).

RBL can also develop students' research abilities. There have been many research results that said if RBL can elevate students' research abilities. This learning approach can grow students' independent learning, critical abilities, creative abilities, and communication skill. Moreover, RBL has been proven to have the carrying capacity of research skills based on learning in higher education (Waris, 2009).

1.2 Biotechnology book and virtual laboratory

Biotechnology is one of the fastest-growing sciences today. The use of biotechnology as a science and tool is compelled for enlarging progress quickly in numerous areas of life. Not only Biotechnology as one of the difficult subjects, but also it is a science that develops very complex and raises debate in various areas such as ethics, politics, and morals. Although it is considered ambiguous, at the same time, it is closely related to improving human welfare. Thus, it still needs control (Bal et al., 2007). Accordingly, the right learning media is necessary to understand the science of biotechnology, one of the learning media that can be used is the research-based textbooks and virtual laboratories. The application of research-based textbooks and virtual laboratories can increase pre-service teachers' understanding of biotechnology and the knowledge of TPACK pre-service teachers.

Learning materials are books that are used as specific fields of study, which are standard books compiled by experts in their fields for instructional purposes, as well as equipped with matching learning facilities to make the user in the school or college can easily understand. Thus, it can support a teaching and learning program (Degeng, 2001). According to Greene and Petty (1981), formulating the function of teaching books is as follows: (1) Reflecting a modern and robust perspective on teaching, (2) Providing a neatly arranged and gradual source of expressional skills, and (3) Presenting materials or facilities matching and practical evaluation and remedial (Degeng, 2001).

A virtual laboratory is a series of laboratory equipment in the form of computer software, which is operated by a computer and can simulate laboratory activities as if the user is in an actual laboratory (Lesmono, Fitriyana, & Wahyuni, 2012). Virtual laboratory learning is the link between theory and practice that can transform passive learning into active learning and stimulate pre-service teachers to think more profoundly and comprehensively. The use of a virtual laboratory can provide opportunities for pre-service teachers to find new ideas in conducting experiments. Pre-service teachers are free to control and use laboratory instruments virtually, so they can carry out trials and errors as well as laboratories work-like by the scientific concepts they received (Muladi et al., 2011).

1.3 Technological Pedagogical Content Knowledge (TPACK)

TPACK is the development of Shulman's Pedagogical Content Knowledge (PCK). Shulman (1986) stated that the combination of Pedagogical Knowledge and Content Knowledge is necessary for teaching and learning. Pedagogical Content Knowledge (PCK) from a teacher is critical in generating innovative learning, which is beneficial for pre-service teachers (Schrum et al., 2007). TPACK is a theoretical concept to integrate technology into teaching processes. The three primary knowledge studies in TPACK are not only in terms of Technological, Content, and Pedagogical Knowledge but also interactions among them (Kohler et al., 2013). The following are a more detail explanation about the relationships among TPACK components.

a) Technological Knowledge (TK)
   Technological Knowledge refers to the ability of teachers to integrate technology into the learning process. It includes the utilization of software and/or hardware of computer, presentation equipment, and learning media. Technological Knowledge also consists of the ability to adapt, learn, and adopt new technologies.

b) Content Knowledge (CK)
Content knowledge heads to the ability of teachers on knowledge or specification of disciplines or subject matter. Content Knowledge differs for each education level. It is also essential since it determines the level of thinking from specific disciplines in each study.

c) Pedagogical Knowledge (PK)
Pedagogical Knowledge discloses the principle direction on how to provide an effective learning environment for students. The term emphasizes the combination of teachers' skills, particularly skills, to manage and organize learning activities based on the expected objectives. The construction of this knowledge is crucial so that pre-service teachers accomplish this fundamental competence.

d) Pedagogical Content Knowledge (PCK)
Pedagogical Content Knowledge links to the statement of Shulman (1986) that effective teaching requires not only the segregation of content and pedagogy. Pedagogical Content Knowledge contains a compelling idea of how to use a specific method to teach specific content. Beyond the separation, PCK tends to accept the specific prompts each other's content and pedagogy.

e) Technological Content Knowledge (TCK)
The reciprocal liaison between technology and content is depicted in Technological Content Knowledge. Technology has a consequence on what we know. It is also an initiation to new information about how we can delineate the content (material) in a diverse fashion that was previously impassable.

f) Technological Pedagogical Knowledge (TPK)
Technological Pedagogical Knowledge pinpoints the reciprocal relationship between technology and pedagogy. Teachers, using this term, will be able to comprehend what technology suitable to accomplish learning objectives. Teacher tends to select the most appropriate and convenient equipment based on its feasibility for a particular pedagogical approach.

Essential features of the terms above describe the importance of TPACK to teaching. TPACK framework serves as a concept for educators to justify the pre-service and in-service teacher's competence in providing a good quality of learning with the aid of technology (Rosyid, 2016).

2. Method

2.1 Research design and participants

The research design used in this study was R2D2 (*Reflective, Recursive, Design, and Development)* development model and *paired sample t-test* to find out differences between before and after using the developed products. The subjects of this study were 32 pre-service teacher-teachers who took biotechnology courses at the Biology Education Study Program at the University of Jember.

Before the testing stage, validation for the product will be applied first. The validator consists of 6 experts, namely: two material experts who will assess the feasibility of content, presentation, and language; two media development experts who will assess the feasibility of graphics in the book and virtual laboratory (Figure 1) as well as two learning media development experts. Moreover, two other validators, as users, precisely two lecturers of biotechnology courses who will assess the feasibility of content, presentation, language, graphic book, and virtual laboratory when applied in the learning. If it has been declared valid, hereafter, a trial is conducted to determine its effect on the pre-service teacher's TPACK.

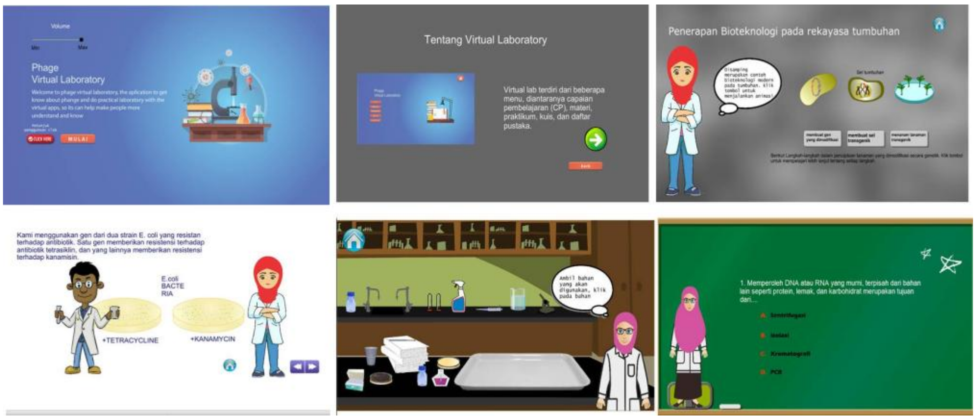

Figure 1. Screenshot Menu of Virtual Laboratory

TPACK measurement instrument uses a questionnaire that is a modification of the existing TPACK questionnaire by using 4 points in the Likert scale, namely: 1=Strongly disagree, 2=Disagree, 3=Agree, and 4=Strongly agree. The TPACK questionnaire was validated by experts and consisted of 40 questions that contained 7 components of TPACK, among others: *Technological Knowledge* (TK), *Content Knowledge* (CK), *Pedagogical Knowledge* (PK), *Pedagogical Content Knowledge* (PCK), *Technological Content Knowledge* (TCK), *Technological Pedagogical Knowledge* (TPK).

Then, we took a step in the test of effectiveness, among others: at the beginning of the lecture meeting, a questionnaire of TPACK which contains 40 questions containing 7 components of TPACK, namely: *Technological Knowledge* (TK), *Content Knowledge* (CK), *Pedagogical Knowledge* (PK), *Pedagogical Content Knowledge* (PCK), *Technological Content Knowledge* (TCK), *Technological Pedagogical Knowledge* (TPK), and *Technological Pedagogical Content Knowledge* (TPACK) is given to the pre-service teachers. The questionnaire was used as preliminary data (pre-test) then continued with learning by using a research-based biotechnology book equipped with a virtual laboratory. After the learning ended, the pre-service teachers were again given the same TPACK questionnaire, and the questionnaire was used as the final data (post-test). This design is used to see a comparison of increasing in pre-service teacher TPACK before and after learning by using research-based biotechnology books equipped with virtual laboratories.

2.2 Data Analysis

The validation results were analyzed using the percentage technique (Utomo et al., 2014), then converted into quantitative data with the criteria in Table 1. If the validation results reached 59.26%, the product could be declared valid. Afterward, the trials implement to pre-service teachers who were taking biotechnology courses to know the effect on pre-service teacher's TPACK. Pre-service teacher's response data is used to measure pre-service teacher opinions about the level of difficulty and readability of a research-based biotechnology book equipped with virtual laboratory during the learning processes, aspects of assessment include aspects of readability, attractiveness, clarity of presentation and usability. The percentage of pre-service teacher responses is calculated using the following formula, and criteria can be seen in Tables 1 and 2.

$$V = \frac{T_{se}}{T_{sm}} \times 100\%$$

Description:

V = Number of scoring scores

Tse = Number of empirical scores

Tsm = Maximum total score

Table 1. Validity criteria

Score interval	Category
19.00≤ Va <39.25	Invalid
39.26 ≤ Va <59.25	Valid Less
59.26 ≤ Va <79.25	Valid
79.26 ≤ Va ≤ 100	Very valid

Table 2. Pre-service teacher response criteria

Percentage of Pre-service Teacher Response	Criteria response
20≤ X <32	Very
32≤ X <44	Not Good
44 ≤ X <56	Good enough
56 ≤ X <68	Good
68 ≤ X ≤ 100	Very Good

The effect test of pre-service teacher's TPACK was analyzed using the average analysis to determine the increase in each TPACK component, in addition to statistical tests to assess the differences before and after the use of research-based biotechnology books with a virtual laboratory using *paired sample t-test* with a significant value of α in 0.05.

3. Results

In this section, the development of a research-based biotechnology book and its effect on elevating TPACK's biology pre-service teacher are analyzed. The development criteria were validity from experts and the level of difficulty and readability through pre-service teachers' responses.

3.1. Development of Research-based Biotechnology Book equipped with Virtual Laboratory

The feasibility and validity of a learning media can be seen from the results of validation and trials. The evaluation result from the experts and the trial are subsequently compared with the validity criteria or effectiveness. Data quantitative is obtained from an assessment of validators analyzed using percentage analysis techniques from the calculation of the average results of the evaluator for six experts (Table 3).

Based on the results of the textbook and virtual laboratory validation in Table 3, it is shown that the validity percentage value of the textbook and virtual laboratory is 86.17%. These results indicate a high validity value. Based on validity criteria, a research-based biotechnology book equipped with a virtual laboratory was categorized as very valid and feasible to use. Book and virtual laboratory that has been validated and revised then is tested to the pre-service teachers who took biotechnology courses.

Table 3. Validation result of biotechnology book and virtual laboratory by experts

No	Validator expert	Aspect	Score (%)		Average score	Category
			1	2		
1	Material	Feasibility content	92.5	92.5	92.5	Very valid
		Feasibility of presentation	92.5	95	93.75	Very valid
		Language	93.18	84.09	88.63	Very valid
Average results of material validation					91. 62	Very valid
2	Media and developers	Feasibility of graphic book	83.33	81.94	82.63	Very valid
		Virtual laboratory feasibility	76.31	76.31	76.31	Valid
		Media development	85.41	81.25	83.33	Valid
Average validation results media					80.75	Valid
3	users	Eligibility contents	88.33	80	84.16	Very valid
		Feasibility presentation	91.07	85.71	88.39	Very valid
		Linguistic	93.75	78.12	85.93	Very valid
Average user validation results					86.16	Very valid
Average validation results for all experts					86.17	Very valid

The test is conducted to determine the level of difficulty and readability of the book and virtual laboratory. The pre-service teachers' responses average of 80.9% (Table 4) as a proof that research-based book equipped with virtual laboratory provide positive responses as well as has a very feasible category to be used as learning material and media for biotechnology course. The book and media are also developed through the stage of improvement based on suggestions and comments provided by experts.

Table 4. The results of the pre-service teacher's responses

Aspect	Percentage (%)	Category
Readability	80.8	Very good
Presentation clarity (material, image, virtual laboratory)	80.3	Very good
Attractiveness	82.3	Very good
Usability / usefulness	80.3	Very good
Average	80.9	Very good

3.2 The effect of Research-based Biotechnology Book equipped with Virtual Laboratory

The test of the effect of using a research-based biotechnology book on pre-service teacher TPACK was obtained from the TPACK questionnaire data given before and after using research-based biotechnology books equipped with a virtual laboratory, then analyzed using the average percentage analysis technique for each TPACK indicator (Figure 2).

Figure 2 shows that the TPACK ability of biology pre-service teachers is good; this can be seen from the average TPACK score on each component lead to an increase. At the beginning of the study, TPACK and other elements got low value because biology pre-service teachers did not know the concept of biotechnology accurately. Consequently, it cannot determine the character of the material; this resulted in pre-service teachers being unable to choose the appropriate technology and teaching methods to teach the material. However, the use of technology in teaching and learning activities can improve pre-service teacher learning motivation, visualize material, and can help the investigation process (Harris et al., 2012; Purwaningsih, 2015).

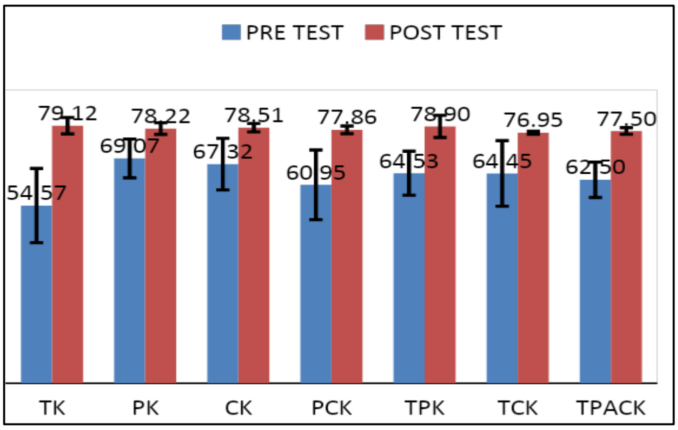

Figure 2. The average value of each component of TPACK

4. Discussion

RBL can train students' thinking skills in solving problems. RBL provides opportunities for students to search for information, formulate hypotheses, collect data, analyze data, and make conclusions on data that has been arranged. One strategy that can be used in research-based learning is enriching teaching materials with the results of lecturer research (Widayati et al., 2010). Books developed based on research are more applicable and help students to have a better understanding of the biotechnology concept. The material presented in the book is also the most up-to-date and useful material for the development of biotechnology in the future, namely about GMO (Genetically Modified Organism) crops, the application of biotechnology in various fields, methods, or biotechnology techniques in producing goods or services that are useful for human life. Besides, the development of appropriate teaching materials and by the needs of the learning community is the best effort to instill learning outcomes (Hera et al., 2014).

The research-based biotechnology book equipped with a virtual laboratory can help pre-service teachers better understand biotechnology processes and techniques that cannot be done through lab work due to laboratory limitations. The existence of a virtual laboratory can be used to support a practicum system that runs conventionally and also provides a visualization of how the practicum is carried out. Besides, it can overcome obstacles that make practicum challenging to do so that molecular biotechnology engineering experiments cannot be carried out in real laboratory because of limitations on tools and materials. Therefore, it can be substituted with a virtual laboratory (Puspita & Yamin, 2008). The virtual laboratory has many benefits, such as (a) Facilitating pre-service teachers to do practicum because all materials and tools have been provided *virtually*; (b) Help the teachers in developing computer simulations as learning media in accordance with the topics presented; and (c) virtual laboratories are safe and suitable to use by pre-service teachers who have a visual learning style because they can explore virtual laboratories according to their speed and needs (Lesmono et al., 2012; Liem et al., 2010).

The research-based biotechnology book equipped with a virtual laboratory has been used to enhance TPACK biology pre-service teachers. Overall, the TPACK component that has the highest enhancement in 24.55 values was found in the component *Technological Knowledge* (TK). One of the factors that cause the TK component has the most significant improvement due to the application of virtual laboratories during learning activities. The results of the pre-test analysis showed that not only most biology pre-service teachers did not know about the technology that could be used to teach biotechnology but also did not consider the use of technology in teaching. These results generally agree with previous research that the use of technology can improve the perception and competence of a teacher in using technology for teaching and learning (Brown & Warschauer, 2006; Paraskeva et al., 2008). Low technology knowledge resulted in low pre-service teacher's TPACK. The reason is TK has a positive influence on TPACK (Purwaningsih, 2015; Ching et al., 2011; Pamuk et al., 2013).

Meanwhile, the component that experienced the lowest improvement was *Pedagogical Knowledge* (PK), which was equal to 9.15. This result could be due to a lack of experience in teaching and facing pre-service teachers directly. The old teaching experience can influence the teaching of the material, proper class arrangements, and determine the correct assessment to find out the misconceptions pre-service teachers may have (Moreland et al., 2006; Harris et al., 2012).

Another component that influences the assessment of TPACK was CK (Content Knowledge). Content Knowledge (CK) includes knowledge of concepts, theories, ideas, the framework of thinking, real knowledge, evidence, law, principles, practices, and approaches to develop such knowledge (Khoiri et al., 2017). Content Knowledge refers to the knowledge or specificity of scientific disciplines or subject matter. Content Knowledge is also necessary because this ability determines the specific way of thinking of particular disciplines in each study (Kohler & Mishra, 2005). In this study, the material that must be addressed was biotechnology. Biotechnology is one of the rapidly developing science today, biotechnology has several characteristics including multidisciplinary science, more applicative nature so that it requires mastery of the basic concepts correctly because the benefits are in direct contact with improving the standard of human life (Sohan et al ., 2003). According to Bal et al. (2007), the ability to understand the concept of biotechnology must be part of the elements supplied to pre-service teachers, as the next generation and members of the community, which are essential components that must master and follow the development of the science. One way that can do is to guide the pre-service teachers' understanding of biotechnology materials by using appropriate teaching materials. The existence of research-based biotechnology books equipped with virtual laboratories makes pre-service teachers better understand biotechnology material, and this can be seen from the high value of student learning outcomes (data not shown) and the increase in TPACK of prospective teachers (Figure 2) after the use of textbooks equipped with virtual laboratories.

Based on the questionnaire that has been filled out by pre-service teachers regarding student responses to the learning that has been carried out, in general, the response was outstanding. This finding shows that the average student feels happy, motivated, and helped by the teaching material being developed. On average, students have mastered the concept or material of biotechnology taught, although there were still some students who have low mastery of concepts, and some lead to misconceptions. The profound understanding and misconceptions can occur because the ability of material analysis of each student is still poorly trained, and students learn textually. A teacher who has gained content knowledge very well will be able to construct material elements simultaneously in working memory and pay attention to students' initial knowledge by giving direction. Besides, they will deliver the material at once or consider prerequisite knowledge (Rahmadani et al., 2016).

Statistical tests using *paired sample t-tests* were conducted to determine differences before and after the use of a research-based biotechnology book equipped with a virtual laboratory. Based on the test results of the *paired sample t-test,* it shows that the significant value is in 0,000, which means the value of sig <α, this indicates that there were significant differences before and after the use of biotechnology book equipped with virtual laboratories against pre-service teacher TPACK. The difference in TPACK of this pre-service teacher is due to the lecture by applying the model of learning using a biotechnology book equipped with a virtual laboratory. Based on the results of research conducted by (Ching et al., 2011; Alayyar et al., 2013; Yeh et al., 2015), it can be seen that the use of technology in lectures proved to be able to increase the TPACK of pre-service teachers.

The TPACK capability is needed for pre-service teachers in the education field because, as prospective teachers, pre-service teachers need to be equipped with teaching skills, concepts, and adequate technological knowledge, which are expected to be later able to help them to do learning appropriately and correctly for their students. When teachers infuse technology into a learning process, students become more interested in learning (Roothaar et al., 2006; Pusparini et al., 2017). Some literature states that the use of technology in learning can improve learning outcomes and pre-service teacher performance (Kohler et al., 2013; Greene & Petty, 1981). One strategy is to see the development of TPACK over time by using pre-assessment and after-use technology in the learning (Griffith Institute for Higher Education, 2008; Harris et al., 2012).

5. Conclusions

This research-based biotechnology book with virtual laboratory provided information on the latest biotechnology development for pre-service teachers. The book was composed of a writer's five years of research experience in relevant topics. It can assist pre-service teachers in understanding ideas, concepts, and theories in the field of biotechnology. They have to master the basic concepts (content) of biotechnology as well as the ability to teach these concepts (pedagogy) correctly and adequately by using technology in learning. The developed research-based biotechnology book equipped with a virtual laboratory was valid and practical to be used in teaching biotechnology for pre-service teachers. Moreover, the use of a biotechnology book based on research with a virtual laboratory can significantly improve pre-service teachers' TPACK. Teaching biotechnology has advanced difficulty level due to multidisciplinary and dynamics fields. Learning material with appropriate media would assist teachers in the teaching and learning process of biotechnology. Thus, biology teachers, as well as pre-service teachers, must have adequate TPACK capabilities of biotechnology. By having a high level of TPACK, they will be able to teach biotechnology concepts to their students properly and correctly following the 21st-century development. The developed research-based biotechnology book with a virtual laboratory could be used for learning biotechnology, especially for developing universities that have no advanced biotechnology laboratory. It is not only to elevate pre-service teachers TPACK but also to give them real-like lab works.

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References
Alayyar, G. M., Fisser, P., & Vogt, J. (2013). Developing Technological Pedagogical Content Knowledge in pre-service science teachers: support from blended learning. *Australian Journal of Educational Technology*, *28*(8), 1298-1316. https://dx.doi.org/10.14742/ajet.773

Bal, S., Samanci, N. K., & Bozkurt, O. (2007). University pre-service teacher's knowledge and attitude about genetic engineering. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(2), 119-126.

Brown, D, & Warschauer, M. (2006). From the university to the elementary classroom: pre-service teacher's experiences in learning to integrate technology in instruction. *Journal of Technology and Teacher Education, 14*(3), 599-62.

Ching, S. C., Koh, J. H. L., Chin, C. T., & Tan, L. L. W. (2011). Modeling of primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Elsevier Journal of Computers & Educations,* 1184-1193.

Degeng, I. N. S. (2001). *Pedoman Penyusunan Bahan Ajar menuju Pribadi Unggul* [Guidelines for preparing superior personal towards learning material]. Surabaya: TEP-PPS University of PGRI Adi Buana Surabaya.

Dyehouse, M., Diefes-Dux, H., Bannet, D. E., & Imbrie, P. K. (2008). Development of an instrument to measure undergraduates' nanotechnology awareness, exposure, motivation, and knowledge. *Journal of Science Education and Technology, 17*(5), 500-510. https://dx.doi.org/10.1007/s10956-008-9117-3

Greene, H. A., & Petty, W. T. (1981). *Developing language skills in the elementary schools*. Boston: Alyn and Bacon, Inc.

Griffith Institute for Higher Education. (2008). *Research-based learning: strategies for successful linking teaching and research*. The University of Griffith.

Harris, J. B., Grandgenett, N., & Hofer, M. (2012). Testing an instrument using structured interviews to assess experienced teacher's TPACK. *Teacher Education Faculty Proceedings & Presentations Paper 15*.

Moreland, J., Jones, A., & Cowie, B. (2006). Developing pedagogical content knowledge for the new sciences: the example of biotechnology. *Teacher Education Journal,* 143-155. https://dx.doi.org/10.1080/10476210600680341

Roothaar, R., Pittendrigh, B. R. & Orvis, K. S. (2006). The Lego® analogy model for teaching gene sequencing and biotechnology. *Journal of Biological Education, 40*(4), 166-17. https://dx.doi.org/10.1080/00219266.2006.9656039

Kohler, M. J., & Mishra, P. (2006). What happens when teachers design educational technology? The development of Technological Pedagogical Content Knowledge. *J. Educational Computing Review, 32*(2), 131-152. https://dx.doi.org/10.2190/0ew7-01wb-bkhl-qdyv

Kohler, M. J., Mishra, P., Akcaoglu, M., & Rosenberg, J. M. (2013). *The Technological Pedagogical Content Knowledge framework for teachers and teacher educators.* Michigan: Michigan State University Department of Counseling, Educational Psychology, and Special Education East Lansing.

Lesmono, A. D., Fitriyana, & Wahyuni, S. (2012). Development of physics practical instructions based on *virtual laboratory* on physics learning in middle school. *Physics Learning Journal, 1*(3), 272-277.

Liem, I., Napitupulu, J., Pangaribuan, A. C., & Turnip, T. N. (2010). Modeling of the virtual science laboratory. *Batam Polytechnic National Seminar, 2*(2), 2085-3858. Batam:Indonesia.

Muladi., Fahmi, A., & Ahmad, A. (2011). Development of interactive multimedia-based virtual biology laboratory. *Seminar on Electrical, Informatics, and Its Education, 3*(10), 65. Malang:Indonesia.

Pamuk, S., Ergun, M., Cakir, R., Yilmaz, H., & Ayas, C. (2013). Exploring relationship among TPACK components and development of the TPACK Instrument. *Educational InfTechnol Springer*.

Paraskeva, F., Bouta, H., & Papagianni, A. (2008). Individual characteristics and computer self-efficacy in secondary teacher education to integrate technology in educational practice. *Computers & Education*, *50*(3), 1084–1091. https://doi.org/10.1016/j.compedu.2006.10.006

Purwaningsih, E. (2015). Strengthening knowledge of physics materials with content representation (CoRe) for prospective physics teachers. *Proceedings of the National Science Education Seminar*. Bandung:Indonesia.

Pusparini, F., Riandi, R., & Sriyanti, S. (2017). Developing Technological Pedagogical Content Knowledge (TPCK) in animal physiology. *IOP Conf. Series: Journal of Physics:* 895 012059. International Conference on Mathematics and Science Education (ICMScE). Bandung:Indonesia.

Puspita, R., & Yamin, M. (2008). Virtual Lab application information system at Gunadarma University information system laboratory. *Proceedings, National Computer Scientific Seminar, and Intelligence System (KOMMIT 2008). ISSN: 1411-6286.* Jakarta:Indonesia.

Roach M., Blackmore P., & Dempster J., (2000), *Supporting high-level learning through research-based methods: interim guideline for course design*. University of Warwick: TELRI Project.

Rosyid. A. (2016). Technological Pedagogical Content Knowledge: a knowledge framework for Indonesian teachers in the MEA era. *Proceedings of the National Seminar on Educational Innovation*. Solo:Indonesia.

Schrum, L., Thompson, A., Maddux, C., Sprague, D., Bull, G., & Bell, L. (2007). Editorial: research on the effectiveness of technology in schools: The roles of pedagogy and content. *Contemporary Issues in Technology and Teacher Education, 7*(1), 456-460.

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Education Researcher, 15*(2), 4-14.

Utomo, A. P., Prihatin, J., & Pujiastuti. (2014). Pengembangan bahan ajar IPA berbasis pendekatan Sains Teknologi Masyarakat (STM) pada pokok bahasan limbah dan penanganannya kelas XI Sekolah Menengah Kejuruan (SMK) [Development of science learning material based on STS approach on waste handling topic in vocational school]. *Pancaran Pendidikan, 3*(4), 163-174.

Waris, A. (2009). Model pembelajaran berbasis riset di Prodi Fisika ITB [Research-based Learning Model in Study Program of Physics Bandung Intitute of Technology]. *Berita Pembelajaran*, *6*(2), 1-3.

Widayati, D. T., Luknanto, D., Rahayuningsih, E., Sutapa G., & Harsono. (2010). Pedoman umum pembelajaran berbasis riset [Manual of research-based learning]. Yogyakarta: Universitas Gajah Mada.

Yeh, F. Y., Lin, T. C., Hsu, Y. S., Wu, H. K., & Hwang, F. K. (2015). Science teachers' proficiency levels and patterns of TPACK in a practical context. *Journal of Science Educational Technology*, *24*(1). https://dx.doi.org/10.1007/s10956-014-9523-7