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Development of Online STEM Learning Program for the Preparation of Prospective 21st Century Biology Teacher

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ABSTRACT

The development of online STEM (science, technology engineering and mathematics) learning programs for prospective Biology teacher students is essential because STEM education can provide several necessary skills needed by biology teachers in the future. This research aims to produce an online STEM learning program by utilizing existing resources around the school. The research method used in this study is a mixed method with a research design: Embedded Experimental Model. Several biology education students (n= 15) were involved in this research. The research began with a preliminary study, drafted a STEM learning program, and developed and implemented a STEM learning program. The instruments used in this study were: learning program assessment sheets, textbook assessment sheets, STEM concept understanding tests, student participation assessments, product assessments, communication skills assessments, EDP assessment rubrics, teaching device assessment rubrics, project assessment rubrics, manufacturing assessment rubric learning videos, online learning observation sheets, and learning observation sheets. Prior to use, all instruments were validated by colleagues and experts. The results of the validation show that, in general, the online STEM learning program and its accessories are suitable for program testing. In terms of the programs being developed, they are effective in improving the abilities of 21st-century biology teacher candidates, and this can be seen from the N-gain score; of 06 obtained. The results of this effectiveness test indicate that the developed learning program can improve the 21st-century abilities of prospective biology teacher student.

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1. INTRODUCTION

Adjustment of learning programs for student teacher candidates, especially biology teachers, needs to be continued to prepare teachers with future abilities. Teachers are an important factor in superior human resources in the future, so adjustments to learning programs must be made continuously. Future teachers need to be equipped with 21st-century adaptive competencies or skills needed in the future (Afandi et al., 2019; Li et al., 2022; Partnership for 21st Century Learning, 2015; Ridwan et al., 2022).

STEM education is an important content in the curriculum for preparing biology teachers for the future (Leung, 2020; Kang, 2019; Dare et al., 2018; (NGSS, 2013). STEM education provides opportunities for science teachers to acquire several important competencies 21st century and other important competencies needed in the future, such as complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, system skills, service orientation, negotiation, cognitive abilities (Elmedina Nikoçeviq-Kurti, 2022; Junaidi et al., 2020; Kusumawardani et al., 2020). In addition, STEM learning experiences can also provide provisions for solving real-world problems, which are important in the 21st century (Elmedina Nikoçeviq-Kurti, 2022). STEM education also provides students with STEM literacy (Al Fatihah et al., 2022; Habig & Gupta, 2022.The important position of STEM education can be why STEM is a subject matter in the Biology Education study program that prepares future teacher candidates.

STEM learning programs must be developed and adaptable to the current situation where students can learn online, offline, and blended learning. Research on developing STEM learning programs has been carried out a lot. Still, online STEM learning programs need to be continuously developed because, until now, there has yet to be a stable STEM education program, especially for preparing prospective biology teachers (Yata et al., 2020).

This condition is an opportunity to design online STEM learning programs to equip students with 21st-century skills and other important abilities. Online STEM learning programs must be developed to facilitate online STEM learning with limited facilities and resources. This is important because STEM learning must be adapted to the conditions of students learning from home in online learning. The development of this STEM learning program is designed to be flexible with the conditions of online learning carried out by students. The STEM learning experience can be designed with the experience of project assignments that students can carry out at home independently and in groups. Online learning based on learning from home allows learning according to context. Of course, learning according to the context will create meaningful and enjoyable learning (Al Fatihah et al., 2022). This learning experience will provide for student-teacher candidates to organize STEM learning experiences at school. In addition, this learning experience also provides provisions for students to conduct STEM learning with very limited resources, utilizing materials and tools that are affordable and easily accessible to students at home.

This research aims to develop STEM learning programs that are implemented online. The research questions from this study are 1) How is the development of STEM Online learning programs; 2) How effective is the online STEM learning program in improving students' 21st-century skills? This lecture program can be implemented to overcome STEM learning problems in the future. STEM education learning programs developed online are expected to equip teachers with the competencies to teach STEM to students. In addition, online learning experiences will provide additional provisions to students regarding how to equip STEM skills that are carried out online.

2. RESEARCH METHOD

The research method in this study uses a mixed method research method with a research design, namely: The embedded Experimental Model (Creswell & Creswell, 2018). Embedded Experimental Design. In this model, qualitative data is attached to quantitative data, and quantitative data is the dominant data. Based on the research method stated above, the steps in implementing research activities are divided into three stages of activity, namely: 1) research preparation stage in the form of field studies and library studies, planning online STEM learning programs and limited trials of online STEM learning programs 2) the implementation stage (implementation of the online STEM learning program that has been developed, and 3) the data interpretation stage to give meaning to the data collected. This online home-based STEM learning will use the Learning Management System (LMS) developed at the Muhammadiyah University of Sukabumi. LMS is used to manage the implementation of online STEM lectures. The research was conducted on students of the Biology Education Study Program, FKIP Muhammadiyah University, Sukabumi. The research subjects were n = 15, who contracted STEM courses.

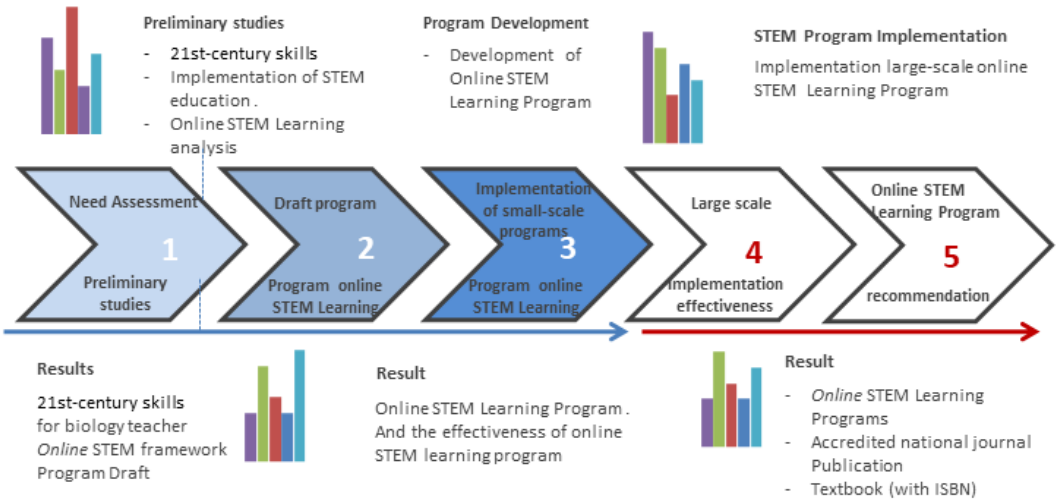

Figure 1. Description of Research Methods and Implementation

This research consists of two main instrument components: instrument components related to the evaluation of online STEM learning programs that will be implemented. Components of instruments related to learning models: Semester Learning Plans (RPS), Student Activity Sheets (LKM), and teaching materials. These instruments were first validated by experts (expert judgment) and tested. Instruments related to model implementation evaluation: 21st-century ability tests for student-teacher candidates, observation sheets of student-teacher candidate abilities in managing online STEM learning based on 21st-century home-based learning, and questionnaires on perceptions of prospective teacher students on STEM online home-based learning programs

applied. The data obtained in this study consisted of qualitative and quantitative data obtained through several instruments that were developed. The table below presents the instruments used in program development.

Table 1 Research Instruments

No	Aspects assessed	Description
1.	Instrument understanding of STEM concept	Used for knowing understanding draft students to STEM concepts and their implementation
3.	Evaluation Participation Student (Peer asessment)	Used for knowing participation students in Workgroup
2	Evaluation STEM products	Used for evaluating products from STEM projects carried out by students
3	Grading rubric ability communicate (in presentation)	Used For knowing the ability communicate with the student
4	EDP assessment rubric	Used for knowing the EDP process in STEM
5	Rubric STEM teaching tools	Used for knowing ability students in develop STEM teaching tools
6	Grading rubric STEM projects	Used for knowing ability students in do STEM project
7	Grading rubric making snippets of STEM learning videos	Used for knowing ability students in make learning video clips
8	Observation Sheet online learning	used for observing online learning through LMS
9	Observation Sheet learning by lecturers	Used for observing learning conducted by lecturers

Research data analysts used sequential data analysis techniques: 1) qualitative data analysis, 2) quantitative data analysis, and 3) combined analysis of quantitative and qualitative data. Analysis of the qualitative data obtained before, during, and after the implementation of the learning model used descriptive analysis, while the quantitative data were analyzed using inferential statistics. Data analysis was carried out using a statistical approach and hierarchy. Statistical analysis was directed at obtaining the N-gain score after the intervention.

Table 2. Score Interpretation Criteria

No	Score Interval (%)	Category
1	81-100	Very Good
2	61-80	Good
3	41-60	Enough
4	21-40	Not enough
5	0-20	Very less

(Kartini & Putra, 2020)

3. RESULT AND DISCUSSION

Preliminary studies

Preliminary studies were carried out to determine the need for the development of online STEM learning programs that will be developed. Preliminary studies were carried out through literature review, observation and interviews. The results of this preliminary study will be used as the basis for developing an online STEM learning program.

The results of a preliminary study of 21st-century skills show that 21st-century competencies are substantial or important competencies to be provided to prospective biology teacher students. This ability needs to be owned because prospective teacher students need to equip these abilities to students. STEM education is one of the important learning experiences that can contribute to acquiring 21st-century skills. STEM education is already part of the curriculum in preparing prospective teachers (Wahono et al., 2020; Kelley et al., 2020; Dare et al., 2018), especially biology teachers, so it is necessary to prepare a special curriculum that is adaptive to prepare biology teachers who can organize STEM learning, especially STEM which can be done online by utilizing local materials. Preliminary studies were carried out on several aspects: preparing 21st-century teacher competencies through STEM Education, STEM frameworks in science teacher learning programs, and online STEM Education by utilizing limited resources.

The teacher's ability to implement STEM is an important factor in future STEM education success. The essential nature of STEM education is mastered by teachers as the basis for implementing STEM education (Dong et al., 2020). STEM teacher preparation programs can be carried out by integrating STEM courses into the curriculum of related study programs. The development of this STEM program is based on the STEM learning dimension (NGSS, 2013), which includes eight science and engineering practices, Cross-Cutting Concepts and

Core Ideas "Content." The scientific process becomes a complete learning experience that teachers in STEM learning must carry out. Thus, both teachers and students must be able to carry out the scientific process. The ability to carry out scientific processes or inquiry abilities in STEM learning is very important. The ability to do inquiry and problem-solving is an absolute standard that must be possessed by teachers and students in order to carry out the STEM learning process (Leung, 2020; Zakeri et al., 2022).

The Covid-19 pandemic has caused significant changes in learning, especially science learning. STEM education, one of the standards for preparing prospective science teachers, must also adapt to conditions where teachers and students have to learn from home. It is necessary to adjust various activities in STEM learning so that they can still be carried out at home without lowering the standard process that has been set. That is a challenge for teachers to design STEM education adaptable to the situation and conditions of the Covid-19 pandemic. In principle, any learning experience, including STEM, can be conditioned through online learning with various advantages (Yılmaz & Malone, 2020; Chiang et al., 2022; Sutaphan & Yuenyong, 2023). through a distance learning system, is carried out with learning management that considers the conditions of students, the student environment and the characteristics of STEM learning. Thus, the STEM learning experience can be carried out through distance learning while still paying attention to the quality of the STEM learning experience according to the characteristics of STEM learning.

Program Development

The development of online STEM learning programs is based on preliminary studies that have been carried out and the learning outcomes that must be possessed after students participate in online STEM learning. This learning program was developed to allow students to carry out STEM learning online with limited resources or utilize existing resources around students. Tables 1 and 2 describe the learning outcomes that describe the content that students will get while participating in the STEM learning program. The program drafts in Tables 1 and 2 results from the validation of biology learning experts and STEM-based learning experts. The results of the expert validation illustrate that, in general, the program draft is suitable for small-scale trials. However, it still needs improvement, including the content that must be provided to students. Expert validators suggest that students be equipped with online learning pedagogy skills as a basis for conducting online STEM learning.

Table 3. Achievements Learning Outcome (LO)

Learning Outcome	Description
LO1	Able to understand and apply basic concepts STEM in Biology learning specific pedagogy
LO2	Able to understand design thinking in STEM (8 practices of STEM learning)
LO3	able to apply cyber pedagogy in online learning as base implementation Online STEM Education
LO4	Do project Online STEM Learning that can do at home by utilizing local materials
LO5	Able to carry out learning activities Online STEM Learning in the context of learning biology by integrating Islamic values and creativity

Achievements learning in Table 3 illustrate competence or ability to be obtained by students after taking part in an online STEM learning program. Where the expected can give ability in students for organize STEM learning online with take advantage source Power limited there is around participant educate.

Table 4 Online STEM Learning Program

week	Sub-LO (as expected final capability)	Learning Indicators	Learning Materials
1	Explain the outline of STEM courses.	Understanding the learning objectives in STEM courses	
2- 3	Able to understand and apply draft deep STEM basics pedagogy Specific learning Biology	Understanding and applying STEM concepts in biology learning: includes: practical dimensions, concept crosscutting dimensions and core idea dimensions	STEM Three-dimensional Learning in STEM
4-5	Able to understand design thinking in STEM (8 practices of STEM teaching)	Understand and apply eight teaching practices (EDP) in STEM learning	Eight teaching practices in STEM Learning
6	able to apply cyber pedagogy in online learning as base implementation STEM Online Learning	Applying cyber pedagogy in online learning	Cyber Pedagogy

week	Sub-LO (as expected final capability)	Learning Indicators	Learning Materials
8-10	Do project STEM Online based problem contextual possible done at home with utilize local materials	Do project Online STEM Learning can do at home by utilizing local materials	STEM projects that can be done at home
10-1 5	Able to carry out activity learning STEM Online in context learning biology with integrate Islamic values and creativity	1. Make STEM learning plans (lesson plan, teaching materials, worksheet, media and evaluation) by integrating Islamic values and ICT. 2. Develop tool evaluation as creatively as possible to assess processes and outcomes in STEM learning. 3. Make learning videos STEM-based that can do at home	Planning and evaluation of STEM-based biology learning that can do at home

The table 4 describes the learning program on the eye STEM course results from studies introduction made. Learning program is a base in developing lesson plans, teaching materials, plans assignments and evaluation eye STEM course. The table under This describes results from the validation of learning programs and assessment instruments used in learning programs.

Table 5 Results Learning Program Validation

No	Indicator Validation	Suggestion
1.	Conformity between learning outcomes	Already in accordance
2.	Achievement suitability in learning with the subject matter and sub-subjects presented in teaching materials	Already in accordance
3.	compatibility between achievements learning with experience learning / online learning strategies	Added knowledge about pedagogy online learning (cyber pedagogy)
4.	compatibility between achievements sheet learning activity developed students	Already in accordance
5	suitability between experience Study with ability 21st century	Already in accordance
5.	Conformity between the evaluation system with learning strategies and outcomes learning	Added knowledge about type instrument specifically for evaluation formative

Results of the validation of learning programs by experts and colleagues (Table 5) show that the STEM education program is generally online Already worth and can proceed to the limited trial stage. Addition content related to cyber pedagogy and Assessment's formative become additional content on the developed teaching materials. The addition of second content can give additional knowledge capital for students to organize their experience of online learning and its evaluation system.

Table 6. Validation Results Instrument Study

No	Instrument Evaluation	Related K21	Assessment Results from Validators
1.	Test understanding of STEM concept	Critical thinking	Worthy
3.	Evaluation Participation Student (Peer asessment)	Collaboration	Worthy
2	Evaluation STEM products	Creativity	Worthy
3	Grading rubric ability communicate (in presentation)	Communications	Worthy
4	EDP assessment rubric	Creativity	Worthy
5	Rubric STEM teaching tools	Creativity	Worthy
6	Grading rubric STEM projects	Collaboration	Worthy
7	Grading rubric making snippets of STEM learning videos	Creativity	Worthy
8	Observation Sheet online learning	Creativity	Worthy
9	Observation Sheet learning by lecturers	Creativity	Worthy

Validation test results to learning programs and instruments made based on improvement of the learning program and its completeness. After repairing to learning programs and completeness, do a trial run limited against programs.

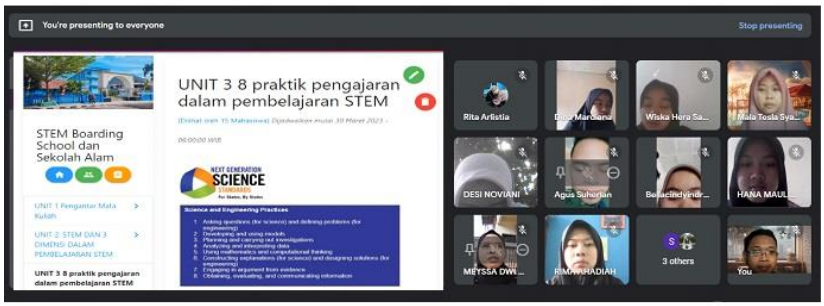

Figure 2. Snippet activity STEM learning through LMS (Learning Management System)

Activity Most of this online STEM learning is carried out at the LMS provided by the university. Activity designed such that students can be involved in activity learning. Activities in the LMS are designed to be varied, starting from activity learning teaching materials, listening to videos, discussions and assignments projects. Activities in the LMS are designed for pedagogy in online learning. This endeavoured framework gets maximum results in online learning (Setiono, 2021; Yılmaz & Malone, 2020; Zakeri et al., 2022).

Activity Online activities are also enriched with several activity-based projects. Project designed to give experience Study meaning for students. Experience Study means it is also orientated To help students gain ability in the 21st century (Li et al., 2022; Wahono et al., 2022). To help the effectiveness learning project, the lecturer developed a number sheet activity to guide the student in carrying out the project.

Sebuah perusahaan memberikan surat kepada anda sebagai seorang praktisi dibidang biologi, perusahaan tersebut menginginkan sebuah alat pembersih sedotan dengan kriteria sebagai berikut:

1. *Alat pembersih tidak merusak sedotan*
2. *Produk aman, cepat, mudah digunakan (maksimal dua menit bisa membersihkan sedotan)*
3. *Produk harus lebih baik dari alat pembersih dipasaran*
4. *Harga produk harus murah, maskimal Rp. 3500*
5. *Bahan harus bersifat local, reuse dan bersahabat dengan lingkungan*

Mari Berfikir Kreatif Mendesain Alat

Biomimikri: isnpirasi dari Alam

Buatlah rancangan alat yang sesuai dengan kriteria yang diinginkan di atas, buat desain gambar beserta rasional dari desain atau gambar rancangan alat pembersih. Sampaikan alat dan bahan dan Langkah kerja pembuatannya.

Figure 3. A snippet of Activity Sheet for Help Student Carry out Online STEM Projects

Figure 3 shows a snippet sheet activity project used to help the student do the project independently at home. STEM projects undertaken by students designed for students can do project Stem at home with source existing power around the home and easily accessed by students so that students can do this STEM project without burdening students. Activity STEM projects are also carried out to give supplies to students' prospective biology teachers so that they can organize similar STEM projects when organizing STEM projects for participant study at school medium first and school medium top. Experience Study projects experienced by students naturally will create experience meaningful learning for the student so that Good in manner direct nor No can supply a number ability important in the future come (Ridwan et al., 2022; Sutaphan & Yuenyong, 2023; Zakeri et al., 2022).

Program Implementation

Program implementation is done to know the effectiveness of learning programs on more scale broad. Implementation of this online STEM learning program done after program development and testing scale small done. At this stage, the program was implemented, which was attended by 15 students taking STEM courses. The result of program implementation shows that this online STEM learning program effectively increases the Skills of 21st-century students. Figure 4 shows the acquisition of N-gain skills of 21st-century students.

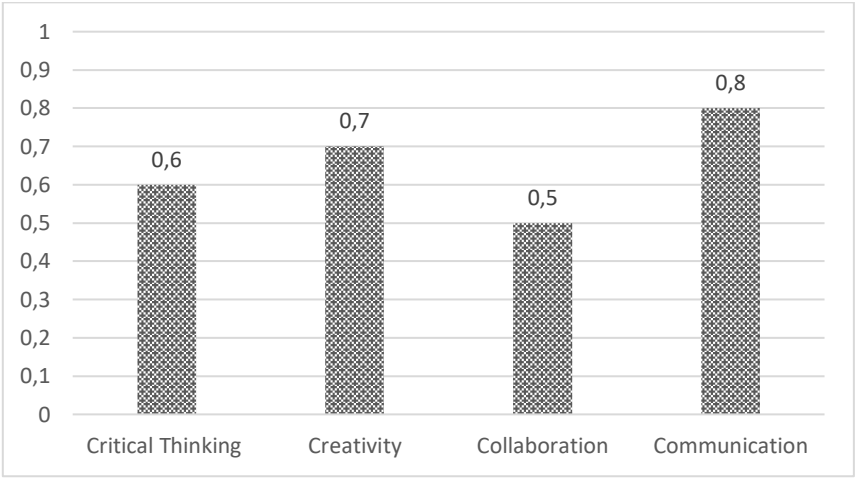

Figure 4. N-Gain 21st Century Skills for Biology Teacher Candidates

Figure 4 shows the enhancement Skills of 21st-century students after participating in an online STEM learning program. Experience a variety of online learning possible; participants obtain a number ability important. Activity watching videos, discussing, criticizing, doing a project, and producing products possible Lots ability can provide to students. Experience Study project through online learning can provide a scientific process and push the creativity of participant educate Because There is an experience in producing a product in an experience Study project (Lidi et al., 2021). Besides That experience learning STEM inside, there is experience project to practice Lots ability like creative, critical, problem-solving, computational thinking and collaboration (Chiang et al., 2022; Li & Xiao, 2022; Zein et al., 2022). Experience online STEM projects in the developed learning program allow participants to educate to think critically and creatively in designing product to finish the problems posed in learning. For example, a student was challenged to develop tool cleaner straw to overcome the problem of straw that can become nest bacteria If not cleaned. The student was challenged to design tools possible cleaner clean straw with fast, cheap and use existing materials around participant educated and recyclable repeat. Experience This gives participants a chance to think critically, be creative and solve the problem.

4. CONCLUSION

Research on the development of online STEM learning programs has produced online STEM learning programs that are suitable for use by prospective biology teacher students. This learning program allows students to learn STEM at home using limited resources. In addition, this online STEM learning program also provides provisions for students to carry out STEM learning online at home with limited resources. It utilizes local materials that are around students. Online STEM learning programs also effectively provide 21st-century skills for prospective biology teacher students

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6. REFERENCES

Chiang, F. K., Zhang, Y., Zhu, D., Shang, X., & Jiang, Z. (2022). The Influence of Online STEM Education Camps on Students' Self-Efficacy, Computational Thinking, and Task Value. *Journal of Science Education and Technology*, *31*(4), 461–472. https://doi.org/10.1007/s10956-022-09967-y

Li, Y., & Xiao, Y. (2022). Authorship and topic trends in STEM education research. *International Journal of STEM Education*, *9*(1). https://doi.org/10.1186/s40594-022-00378-4

Li, Y., Xiao, Y., Wang, K., Zhang, N., Pang, Y., Wang, R., Qi, C., Yuan, Z., Xu, J., Nite, S. B., & Star, J. R. (2022). A systematic review of high impact empirical studies in STEM education. *International Journal of STEM Education*, *9*(1), 1–18. https://doi.org/10.1186/s40594-022-00389-1

Lidi, M. W., Daud, M. H., & Program, E. S. (2021). Project-based learning based on local wisdom through google classroom to improve process skills in pandemic times. *Bioedukatika*, *9*(3), 169–178.

Ridwan, A., Fatimah, C., Hadinugrahaningsih, T., Rahmawati, Y., & Mardiah, A. (2022). Development of 21 st Century Skills in Acid-Base Learning Through STEAM Projects. *JTK: Jurnal Tadris Kimiya*, *7*(1), 121–134.

Setiono, S. (2021). Analisis Respon Mahasiswa dalam Pembelajaran Online Berbasis Aktifitas di Perguruan Tinggi. *Jurnal Pendidikan*, *9*(2), 15–23. https://doi.org/10.36232/pendidikan.v9i2.1095

Sutaphan, S., & Yuenyong, C. (2023). Enhancing grade eight students' creative thinking in the water STEM education learning unit. *Cakrawala Pendidikan*, *42*(1), 120–135. https://doi.org/10.21831/cp.v42i1.36621

Wahono, B., Hariyadi, S., & Subiantoro, A. W. (2022). The development of an online STEM teacher professional development package with the DECODE model: An innovative teacher's quality maintenance. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(12). https://doi.org/10.29333/ejmste/12647

Yılmaz, Ö., & Malone, K. L. (2020). Preservice teachers perceptions about the use of blended learning in a science education methods course. *Smart Learning Environments*, *7*(1). https://doi.org/10.1186/s40561-020-00126-7

Zakeri, N. N. binti, Hidayat, R., Sabri, N. A. binti M., Yaakub, N. F. binti, Balachandran, K. S., & Azizan, N. I. binti. (2022). Creative methods in STEM for secondary school students: Systematic literature review. *Contemporary Mathematics and Science Education*, *4*(1), ep23003. https://doi.org/10.30935/conmaths/12601

Zein, L. S. H., Setiono, S., & Windyariani, S. (2022). Pengaruh Pendekatan STEMA Terhadap Kemampuan Berpikir Kreatif Peserta Didik Kelas VIII SMP Pada Materi Sistem Pencernaan. *Biodik*, *8*(2), 90–102. https://doi.org/10.22437/bio.v8i2.16990