JISE 13 (2) (2024): 64-73

Journal of Innovative Science Education

https://journal.unnes.ac.id/journals/jise/

Performance Assessment Creative Thinking Rubric in Science Technology Engineering and Mathematics (STEM) Learning

Sistiana Windyariani ✉, Setiono Setiono

Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Muhammadiyah Sukabumi, Jalan R. Syamsudin SH. No. 50 Sukabumi, Jawa Barat Indonesia

Article Info

Article History :
January 2024
Accepted
March 2024
Published
August 2024

Keywords:
Creative Thinking; Performance Assessment; STEM

Abstract

This research has the objective to develop an alternative rubric for evaluating creative thinking performance in STEM (Science, Technology, Engineering, and Mathematics) education. The research employs a Design-Based Research (DBR) methodology, which involves four stages: 1) Designing a prototype for performance assessment (design), 2) Conducting trials to test the developed assessment (test), 3) Performing evaluations, and 4) Reflecting on and addressing any deficiencies in the developed tasks and rubrics. The research involved respondents completing performance assessment tasks using the newly developed criteria/ rubric. The participants included 57 students from the Biology Education research Program at Universitas Muhammadiyah Sukabumi, enrolled in the 3rd and 5th semesters. This research resulted in a valid and practical assessment of creative thinking performance in STEM learning, with the Performance Assessment Rubric achieving an average percentage of 83.5% (proper). The research produced a creative thinking performance assessment instrument that can be used as an evaluation tool in STEM education. Further implications suggest incorporating these assessments into STEM curricula and training educators to use them effectively.

✉ correspondence:
Jalan R. Syamsudin SH. No. 50 Sukabumi, West Java
Indonesia 43113
E-mail: windyariani@ummi.ac.id

p-ISSN 2252-6412
e-ISSN 2502-4523

INTRODUCTION

STEM (Science, Technology, Engineering, and Mathematics) education is a field that integrates science, mathematics, technology, and engineering. It aims to provide meaningful learning experiences by systematically combining knowledge, concepts, and skills. STEM education has been shown to effectively develop a range of skills, including Higher Order Thinking Skills (HOTS), problem-solving, collaboration, critical and creative thinking, reasoning, and decision-making (Zein, Setiono, Windyariani, 2022; Chania, et al., 2020; Yusuf et al., 2018). According to several studies, STEM education is also considered effective in fostering the 4 Cs: Creative Thinking, Critical Thinking, Communication, and Collaboration (Ardwiyanti, et al., 2021; Kurniasih, et al., 2020; Sumarni, et al., 2019; Bicer. et al., 2017).

STEM, as an interdisciplinary learning approach, can enhance students' creative problem-solving skills, a key indicator of 21st-century competencies (Nuraziza & Suwarma, 2018). STEM education is believed to equip students with the ability to apply their knowledge to create or design products using technology as a problem-solving tool (Permanasari, 2016). The process of designing or creating products within STEM education necessitates creative thinking skills. These skills are crucial as they enable individuals to become more productive by being more sensitive and adaptable. Creative Thinking Skills involve using innovative approaches to solve problems, fostering innovation, and making discoveries. Creative thinking is often equated with the capacity to generate novel ideas (Piaw, 2010). Various experts have defined creative thinking in different ways. According to Zubaidah (2018), it involves the ability to identify problems, make hypotheses, generate new ideas, and communicate the results. Hotaman (2008) describes creative thinking as the ability to establish connections between previously unlinked relationships, producing new and original thoughts and experiences that form new patterns within a schema. Additionally, creative thinking can be seen as the capability to create a new object or concept or to enhance an existing product to make it more appealing (National Education Association, 2010; Partnership for 21st Century Learning, 2015). Another definition describes creative thinking skills as the ability to discover new, previously non-existent, and original things, as well as to develop various new solutions for each problem, encompassing the generation of new, varied, and unique ideas (Leen, et al., 2014). This skill entails truly new and original actions, whether unique to the individual or culturally significant (Abdullah & Osman, 2010). According to research by Setiono & Windyariani (2023), project-based learning experiences through STEM education can enhance the understanding of scientific processes and train creative thinking skills due to the hands-on experience involved in producing a project.

To effectively assess creative thinking in STEM education, suitable assessment methods are required. Alternative assessments are particularly appropriate for evaluating creative thinking in STEM learning. The primary feature of alternative assessments is that they not only measure student learning outcomes but also provide detailed and clear information about the learning process. This approach aligns with cognitive flexibility theory (Spiro, 1990), which emphasizes that learning is an ongoing process that must adapt to changing contexts and situations. Therefore, assessment should be integrated within the learning context and not conducted in isolation from the current situation. One effective alternative for measuring creative thinking abilities is performance assessment. This type of assessment is noted for its flexibility in educational contexts (Stiggins, 1994; Oktriawan, 2015). Performance assessment is grounded in four key principles: 1) it is based on active student participation, 2) the tasks assigned to students are integral to the entire learning process, 3) the assessment not only evaluates the students' current learning status but also aims to enhance the learning process itself, and 4) by understanding the criteria used to measure and assess their success, students are motivated to actively and transparently strive towards achieving their learning objectives.

Performance assessments are particularly effective for measuring complex learning outcomes such as creative thinking and problem-solving skills. They are defined as the direct and systematic observation of both the process and the product of performance. Performance assessments comprise two components: tasks and criteria/rubrics.

Examples of performance assessment tasks include oral presentations, essays, science fair projects, and research projects (Stiggins, 1994).

Assessments must be based on established criteria/rubrics, which serve as the foundation for evaluating performance and demonstrating mastery of specific competencies (Wulan, 2018). Rubrics facilitate performance assessments, making them easier to conduct and more objective. Without a rubric, consistently assessing performance is challenging. However, research indicates that educators often struggle to design and create appropriate assessment rubrics (Nurlenasari, et al., 2019). Furthermore, interdisciplinary STEM education requires adequate assessment to accurately measure students' interdisciplinary understanding of science, technology, engineering, and mathematics (Griese, et al., 2015; You, et al., 2018).

Given the aforementioned description, this research addresses the need by developing a performance assessment that offers a comprehensive view of students' creative thinking abilities. It underscores the importance of creating creative thinking performance assessment rubrics in university-level STEM courses. These rubrics provide an alternative means for conducting assessments that are objective, valid, and practical. The research combines creative thinking evaluation with both theoretical and practical aspects of STEM education by integrating the assessment into the STEM curriculum, thereby providing a holistic approach to student assessment..

METHODS

The research method employed is Design-Based Research (DBR) (Scott & Doherty, 2020). DBR is a methodological approach suitable for developing a product, specifically a creative thinking performance assessment model in STEM learning for the anti-diabetes moci project. The research involved 57 students from the Biology Education research Program at Universitas Muhammadiyah Sukabumi, enrolled in the 3rd and 5th semesters.

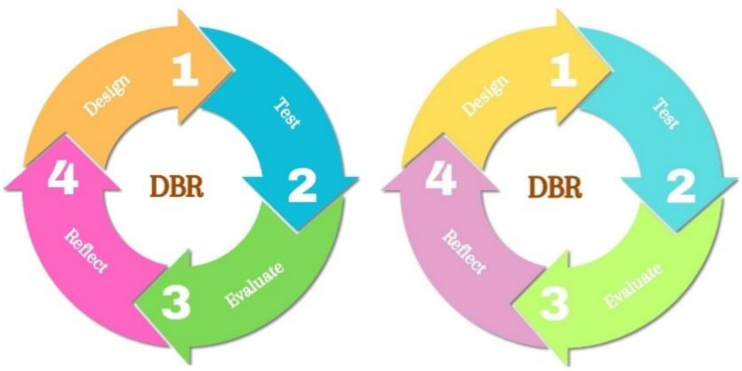

Figure 1. Design Based Research (DBR) flow according to Scott & Doherty (2020)

The research was conducted in several stages: First, problems were identified and analyzed through literature reviews on creative thinking performance assessments and initial observations of performance assessment usage. Based on these outcomes, a product design for creative thinking performance assessments was created. In the second stage, the product was tested through task simulations and developed performance assessment rubrics. During the testing phase, the third stage involved evaluating the teaching tools, focusing on their effectiveness and shortcomings. The fourth stage involved reflecting on the model trials, identifying the strengths and weaknesses of the developed assessment, and determining how the research addressed the underlying theory. This process continued with additional cycles of identifying, designing, testing, and reflecting to refine the creative thinking performance assessment model in STEM learning.

The instruments utilized in this research include questionnaires and validation sheets. The creative thinking framework, developed based on EdLeader 21, comprises the following components: 1) Idea generation, 2) Idea design and refinement, 3) Creative production and innovation, 4) Openness and courage to explore, 5) Working creatively with others, and 6) Self-regulation and reflection. Students were given questionnaires to respond to the performance assessment, which was evaluated based on four indicators: the benefits of the instrument, and its strengths and weaknesses. Expert validation sheets for the instrument were prepared based on indicators such as rubric format, rubric quality, language, writing system, and the benefits of performance assessment. The data analysis technique followed the Miles & Huberman model (Miles & Huberman, 1994), which includes: 1) Data condensation, involving the selection and simplification of the data, 2) Data presentation, using tables, charts, descriptions, or schemes, and 3) Drawing and verifying conclusions from the research data.

RESULTS AND DISCUSSION

This research aims to develop an alternative rubric for assessing creative thinking performance in STEM (Science, Technology, Engineering, and Mathematics) education. The research employs the Design-Based Research (DBR) method (Scott & Doherty, 2020). In the initial stage, the research involves identifying and analyzing problems through literature reviews related to creative thinking performance assessments and initial observations of performance assessment usage. Initial observations reveal that many lecturers are still focused solely on assigning numerical scores during assessments. The core purpose of assessment is to provide feedback on students' demonstrated abilities, facilitating the achievement of learning outcomes. Thus, assigning numerical scores should not be seen as the final goal but rather as part of the broader process of evaluating learning outcomes. This aligns with research outcomes by Triwulandari et al. (2015), which highlight the frequent challenges in selecting suitable assessment methods for specific abilities. For instance, some lecturers still use written exams to assess psychomotor skills, although these skills should ideally be evaluated through performance assessments..

The second stage involves designing a product in the form of a creative thinking performance assessment, grounded in theoretical frameworks derived from literature reviews and outcomes from initial observations. The creative thinking framework, based on EdLeader 21 (2014), consists of six elements: 1) Idea generation, 2) Idea design and refinement, 3) Creative production and innovation, 4) Openness and courage to explore, 5) Working creatively with others, and 6) Self-regulation and reflection. Developing this creative thinking performance assessment is inherently tied to the STEM course itself, meaning it is integrated with the course plan (RPS). The STEM application course in Biology Education aims to provide students with an understanding of integrating biological sciences with mathematics, technological engineering, and ICT to develop problem-solving, critical thinking, and creative thinking skills. This course facilitates students not only to research existing STEM applications but also to practice designing, compiling, applying, and evaluating STEM learning in Biology education at school. The Course Learning Outcomes (CPMK) for this course include in Table 1:

Table 1. STEM Subject Learning Achievements

CPMK	CPMK statement
CPMK 1	Capable of comprehensing and creatively applying fundamental STEM concepts within the context of specific biology teaching pedagogy.
CPMK2	Capable of comprehending and creatively implementing design thinking within the eight STEM teaching practices.
CPMK 3	Capable of creatively applying cyber pedagogy in online learning as a foundation for implementing Online STEM Education.
CPMK 4	Executing Online STEM Education projects based on real-world problems that can be tackled at home by creatively utilizing local materials.
CPMK 5	Capable of conducting online STEM Education activities within a biology learning context by integrating creativity.

In STEM classes, students are tasked with completing online STEM projects that revolve around real-world issues and can be accomplished at home using locally sourced materials in inventive ways. Performance evaluation tools are crafted by merging project tasks or real-world problems that stimulate students' creative thinking. The assessment criteria encompass creativity, the application of STEM principles, and communication abilities. The developed rubric includes these dimensions (Table 2):

Table 2. Creative Thinking Performance Assessment Rubric developed

Criteria	Score 1-2	Score 3-4	Score 5-6	Score 7-8	Score 9-10
Idea Generation	Unable to generate broad concepts or ideas.	Generates ideas that are somewhat original but still broad in scope.	Produces unique and context-specific ideas.	Produces highly original ideas and introduces new contributions.	Produces ideas that are exceptional, innovative, and have the potential to create new opportunities.
Idea design and refinement	Does not create or improve ideas.	Designs or refines an idea adequately, though with some shortcomings.	Executes designs or enhances ideas effectively and clearly.	Executes designs or refines ideas excellently and with great detail.	Executes exceptional designs or enhancements to ideas, resulting in elegant and effective solutions.
Creative Production and Innovation	Does not engage in significant creative production or innovation.	Engages in adequate creative production or innovation, though there are some shortcomings.	Engages in creative production or innovation that is effective and contextually appropriate.	Engages in creative production or innovation that is outstanding and has a positive impact.	Engages in remarkable creative production or innovation, leading to significant change.
Openess and Courage to explore	Lacks the courage to explore or think openly.	Demonstrates limited willingness to explore or think openly.	Exhibits good courage in exploring and thinking openly.	Exhibits outstanding courage in exploring and thinking openly.	Displays exceptional courage to explore, experiment with new ideas, and maintain an open-minded approach to different concepts.
Work Creatively with others	Unable to collaborate creatively with others.	Collaborates somewhat creatively with others, though there is some imbalance.	Collaborates effectively with others in a creative manner, fostering synergy.	Collaborates creatively with others, generating strong synergy.	Collaborates with others in an exceptionally creative manner, making significant joint contributions.
Self Regulation and Reflection	Lacks the ability to self-regulate or reflect.	Shows a limited ability to self-regulate or reflect.	Displays a strong ability to self-regulate and reflect..	Exhibits outstanding ability to self-regulate and reflect.	Shows exceptional ability to self-organize, learn from experience, and continuously improve.

In this research, the developed instruments included assignments and rubrics, which will be implemented using the observation method. This aligns with Septiani's (2017) research, which found that observations can better describe students' actual abilities compared to tests. The instrument encompasses important aspects of creative thinking performance, in line with EdLeader 21. Additionally, evaluation and learning experts have assessed the instruments to ensure they are relevant and cover the desired dimensions. The results of the expert validation are as follows in Table 3:

Table 3. Expert Validation Results

Rated aspect	Average percentage	Category
Conformity of the rubric to the indicators	80.33	High
Rubric construction	82.50	High
Rubric readability	85.66	Very high

Based on the validation results, several sentence improvements are necessary. The next step involves the third phase: evaluating the teaching tools with emerging evidence about their effectiveness and shortcomings. The validated and refined instrument was tested with a small group of participants (10 students) to gather initial feedback on its validity and reliability. During this phase, the task, a STEM project based on contextual problems using local materials, is evaluated using a developed rubric. Students are required to create a video for the project, which is then assessed by one observer lecturer who evaluates the creative thinking performance in the videos. After the assessment, the observer lecturer completes a questionnaire. The results of the initial trials are presented in Table 4 below:

Table 4. Initial trial results

Rated aspect	Average percentage	Category
Conformity of the rubric to the indicators	82.10	High
Rubric construction	84.44	High
Rubric readability	83.33	High

Based on the initial trial, no revisions were needed, so a field trial was conducted with a larger group of students (47 students). At this stage, the task, a STEM project based on contextual problems using local materials, is evaluated using a developed rubric. Students are required to create a video for the project, which is then assessed by three observer lecturers who evaluate the creative thinking performance in the videos. After the assessment, the observer lecturers complete a questionnaire. The results of the initial trials are presented in Table 5 below:

Table 5. More extensive trial results

Rated aspect	Average percentage	Category
Conformity of the rubric to the indicators	87.30	Very high
Rubric construction	86.33	Very high
Rubric readability	83.33	High

The results from the three observers, who filled in the rubric for 47 students, were summarized and converted into a percentage of similarity in rubric completion. These outcomes are presented in Table 6 below:

Table 6. Percentage and Eligibility of Performance Assessment Rubrics

Rated aspect	Score Similarity	Maximum Score	Percentage	Criteria
Idea generation	48	60	80%	Proper
Idea design and refinement	53	60	88%	Proper
Creative Production and Innovation	52	60	86%	Proper
Openness and Courage to explore	50	60	83%	Proper
Work Creatively with Others	50	60	83%	Proper
Self Regulation and Reflection	49	60	81%	Proper

From Table 5, it can be seen that all six aspects have been deemed feasible, as they have exceeded 80%. The next stage involves reflecting on the results of model testing and identifying the advantages and disadvantages of the developed assessment. This stage involves interviewing lecturers and students to gain a deeper understanding of the observers' (lecturers) and students' experiences during the assessment. The feedback obtained is used to refine and enhance the effectiveness of the instrument. This process continues with the next cycle of identifying, designing, testing, and reflecting to perfect the creative thinking performance assessment model in STEM learning. This iterative process ensures that the creative thinking performance instruments in STEM learning are effective, consistent, and reliable.

Performance assessments have their own advantages and disadvantages. The main advantage is that they provide a more comprehensive evaluation of various forms of reasoning, communication, and motor skills, enabling the assessment of learning processes and outcomes in more complex abilities (Wulan, 2018). However, the disadvantages include high costs and significant time commitments (Arifin, 2012). Therefore, while performance assessments are valuable for evaluating students' abilities, there are important considerations to keep in mind when designing them. These considerations include: (1) not all learning objectives in each basic competency need to be assessed through performance evaluations; (2) when creating the instrument, it is important to consider the scoring and the quality of each criterion; and (3) attention must be paid to the time required to complete and review performance tasks (Moch, 2019).

STEM (Science, Technology, Engineering, and Mathematics) education emphasizes the development of creative thinking skills as a cornerstone for innovation and advancement in science and technology. In STEM learning, students engage in meaningful activities to grasp concepts. They are then encouraged to explore through project activities, ensuring active involvement in the process. This approach promotes critical, creative, and analytical thinking, enhancing high-level thinking skills (Capraro & Slough, 2013). These outcomes are consistent with the research conducted by Septiani (2016), which suggests that science subjects become more comprehensible when learning activities are connected to real-world scenarios. This approach can stimulate students' curiosity and interest, enabling them to analyze and assess everyday processes. Additionally, the use of STEM-based educational resources can enhance students' creative thinking, reasoning skills, conceptual comprehension, and critical thinking abilities (Fitriani et al., 2017; Pangesti et al., 2017).

Performance assessment can be effectively implemented if the user is familiar with and understands the criteria outlined in the instrument. Therefore, it is essential to align perceptions before conducting assessments, and the technical steps of the activity must correspond with the ongoing learning activities. Challenges encountered during the assessment included videos that were insufficiently supportive and lacked coherence during the STEM project creation activities. This aligns with the research by Nurlenasari et al. (2019), which indicates that videos are less supportive for lecturers in making observations. Moreover, the extensive number of elements that need to be observed requires respondents to spend additional time reviewing students through video clips (Utomo et al., 2019). Developing a validated rubric adds to the existing knowledge on educational assessments, offering a basis for future studies on creative thinking and interdisciplinary learning. This research has the potential to enhance the understanding and evaluation of students' creative thinking abilities within STEM learning environments and support the creation of more innovative and pertinent STEM education practices..

CONCLUSION

This research develops a performance assessment tool for evaluating creative thinking, which can be utilized within the context of STEM education. Additional implications involve incorporating these assessments into STEM curricula and training educators to effectively implement them.

ACKNOWLEDGEMENTS

Gratitude is extended to the Ministry of Education and Culture, Research and Technology Indonesia for providing financial support for this research.

REFERENCES

Abdullah, M., & Osman, K. (2010). Scientific inventive thinking skills among primary students in Brunei. *Procedia-Social and Behavioral Sciences*, 7, 294-301. Scientific

Inventive Thinking Skills among Primary Students in Brunei - ScienceDirect

Alfin, M. B., Cahyono, E., Ridlo, S., Sumarni, W., & Widiyatmoko, A. (2024). The Validity of the Guided Inquiry-Based Teaching Module on Additives to Improve Students' Scientific Attitudes. *Journal of Innovative Science Education*, *13*(1), 12-19.

Ardwiyanti, D., Prasetyo, Z. K., & Wilujeng, I. (2021). STEM research trends in indonesia: A systematic literature review. *Journal of Science Education Research*, *5*(1), 38-45. 41752-116687-1-PB-libre.pdf (d1wqtxts1xzle7.cloudfront.net)

Arifin, Z. (2012). Evaluasi pembelajaran. In Direktorat Jendral Pendidikan Islam Kementrian Agama 2012

Bicer, A., Capraro, R. M., & Capraro, M. M. (2017). Integrated STEM assessment model. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3959-3968. Integrated STEM Assessment Model - Eurasia Journal of Mathematics, Science and Technology Education (ejmste.com)

Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why now? An introduction to STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach. In *STEM project-based learning* (pp. 1-5). Brill. Why PBL? Why STEM? Why Now? An Introduction to STEM Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics(STEM) Approach in: STEM Project-Based Learning (brill.com)

Chania, D. M. P., Medriati, R., & Mayub, A. (2020). Pengembangan bahan ajar fisika melalui pendekatan STEM berorientasi HOTs pada materi usaha dan energi. *Jurnal Kumparan Fisika*, *3*(2), 109-120. Pengembangan Bahan Ajar Fisika Melalui Pendekatan Stem Berorientasi Hots Pada Materi Usaha Dan Energi | Jurnal Kumparan Fisika (Unib.Ac.Id)

EdLeader21. (2014). *4Cs RUBRICS : Additional Resources*. 1–18

Fitriani, D., Kaniawati, I., & Suwarna, I. R. (2017). Pengaruh pembelajaran dengan pendekatan STEM pada konsep tekanan hidrostatis terhadap causal reasoning siswa SMP. In *Prosiding Seminar Nasional Fisika*.

Griese, B., Lehmann, M., & Roesken-Winter, B. (2015). Refining questionnaire-based assessment of stem students' learning strategies. International Journal of STEM Education, 2(1), 12. Refining questionnaire-based assessment of STEM students' learning strategies | International Journal of STEM Education | Full Text (springeropen.com)

Hotaman, D. (2008). The Examination of the basic skill levels of the students in accordance with the perceptions of teachers, parents and students. *International Journal of Instruction*, 1(2), 39-55. Microsoft Word - iji_2008_2_3.doc (dergipark.org.tr)

Kurniasih, Y., Hamdu, G., & Lidinillah, D. A. M. (2020). Rubrik asesmen kinerja berpikir kritis pada pembelajaran STEM dengan media lightning tamiya car. *Jurnal Ilmiah Sekolah Dasar*, *4*(2), 174-185. Rubrik Asesmen Kinerja Berpikir Kritis pada Pembelajaran STEM dengan Media Lightning Tamiya Car | Jurnal Ilmiah Sekolah Dasar (undiksha.ac.id)

Leen, C.C., Hong, H., Kwan, F.F.H. & Ying, T.W. 2014. *Creative and Critical Thinking in Singapore Schools*. Singapore: National Institute of Education, Nanyang Technological University. researchgate.net

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. sage.

Moch. (2019). *Panduan penilaian kinerja (performance assessment)*. Pusat Penilaian Pendidikan

National Education Association. (2010). *Preparing 21st century students for a global society: An educators guide to the "Four Cs*". Retrieved September 16, 2018, from National Education Association: http://www.nea.org/assets/docs/A-Guide-to-Four-Cs.pdf

Nuraziza, R., & Suwarma, I. R. (2018). Menggali Keterampilan Creative Problem Solving yang Dimiliki Siswa SMP Melalui Pembelajaran IPA Berbasis STEM. *WAPFI (Wahana Pendidikan Fisika)*, *03*(01). menggali Keterampilan Creative Problem Solving Yang Dimiliki Siswa Smp Melalui

Pembelajaran Ipa Berbasis Stem | Nuraziza | Wapfi (Wahana Pendidikan Fisika) (Upi.Edu)

Nurlenasari, N., Lidinillah, D. A. M., Nugraha, A., & Hamdu, G. (2019). *Assessing 21 st century skills of fourthgrade student in STEM learning*. https://doi.org/10.1088/1742-6596/1318/1/012058

Oktriawan, T., Fadiawati, N., & Rosilawati, I. (2015). Pengembangan Instrumen Asesmen Kinerja Pada Praktikum Pengaruh Luas Permukaan Terhadap Laju Reaksi. *Jurnal Pendidikan dan Pembelajaran Kimia*, *4*(2), 593-604. article.php (kemdikbud.go.id)

Pangesti, K. I., Yulianti, D., & Sugianto, S. (2017). Bahan ajar berbasis STEM (Science, Technology, Engineering, and Mathematics) untuk meningkatkan penguasaan konsep siswa SMA. *UPEJ Unnes Physics Education Journal*, *6*(3), 53-58.

Partnership for 21st Century Learning. (2015). *P21 Framework Definition*. Retrieved September 15, 2018, from http://www.p21.org/our-work/p21-framework/P21_Framework_Definitions_New_Logo2015.pdf

Piaw, C.Y. (2010). Building a test to assess creative and critical thinking simultaneously. *Procedia Social and Behavioral Sciences*, 2:551—559 Building a test to assess creative and critical thinking simultaneously - ScienceDirect

Permanasari, A. (2016). STEM Education: Inovasi dalam Pembelajaran Sains. *Proseding SNPS*. 23-24. 7245 (uns.ac.id)

Scott, E. E., Wenderoth, M. P., & Doherty, J. H. (2020). Design-based research: A methodology extend and enrich biology education research. *CBE—Life Sciences Education*, *19* (2), es11. Design-Based Research: A Methodology to Extend and Enrich Biology Education Research | CBE—Life Sciences Education (lifescied.org)

Septiani, A. (2016). Penerapan Asesmen Kinerja dalam Pendekatan Stem (Sains Teknologi Engineering Matematika) untuk Mengungkap Keterampilan Proses Sains. *Proseding SNPBS.* Penerapan Asesmen Kinerja dalam Pendekatan Stem (Sains Teknologi Engineering Matematika) untuk Mengungkap Keterampilan Proses Sains (ums.ac.id)

Septiani, A., & Rustaman, N. (2017). Implementation of Performance Assessment in STEM (Science, Technology, Engineering, Mathematics) Education to Detect Science Process Skill. *Journal of Physics: Conference Series, 812*.

Setiono, S., & Windyariani, S. (2023). Development of Online STEM Learning Program for the Preparation of Prospective 21st Century Biology Teacher. *BIOEDUKASI*, 181-188. jurnal.unej.ac.id

Spiro R. J & Jehg, J. (1990). *Cognitive Flexibility and Hypertext: Theory and Technology for the non linear and multidimensional reversal of complex Subject Matter,* Cognition, Education, and Multimedia, Hilsdale, NJ, Erlbaum.

Stiggins, R. J. (1994). *Student-centered classroom assessment*. New York: Merrill.

Sumarni, W., Wijayati, N., & Supanti, S. (2019). Analisis kemampuan kognitif dan berpikir kreatif siswa melalui pembelajaran berbasis proyek berpendekatan STEM. *J-PEK (Jurnal Pembelajaran Kimia)*, *4*(1), 18-30.kemampuan-Kognitif-Dan-Berpikir-Kreatif-Siswa-Melalui-Pembelajaran-Berbasis-Proyek-Berpendekatan-Stem.pdf (researchgate.net)

Triwulandari, S., Windyariani, S., & Ramdhan, B. (2015). Pengembangan Instrumen Asesmen Autentik Untuk Praktikum Morfologi Tumbuhan. *Utile: Jurnal Kependidikan*, *1*(2), 170-179. Pengembangan Instrumen Asesmen Autentik Untuk Praktikum Morfologi Tumbuhan - Repository UMMI

Utomo, S. W., Ubaidillah, M., Joyoatmojo, S., Yutmini, S., & Suryani, N. (2019). Improving Students' Creativity in Video Making by Problem Based Learning Model. *International Journal of Educational Research Review*, *4*(3), 481-488. International Journal of Educational Research Review » Submission » Improving Students' Creativity in Video Making by Problem Based Learning Model (dergipark.org.tr)

Wulan A, R. (2018). *Menggunakan Asesmen Kinerja untuk Pembelajaran Sains dan Penelitian. Bandung*: UPI Press.

You, H. S., Marshall, J. A., & Delgado, C. (2018). Assessing students' disciplinaryand interdisciplinary understanding of carbon cycling. *Journal of Research in Science Teaching, 55(3), 377–398*. Assessing students' disciplinary and interdisciplinary understanding of global carbon cycling - You - 2018 - Journal of Research in Science Teaching - Wiley Online Library

Yusuf, I., Widyaningsih, S. W., & Sebayang, S. R. B. (2018). Implementation of E-learning based-STEM on quantum physics subject to student HOTS ability. *Journal of Turkish Science Education*, *15*(STEM Special Issue), 67-75.

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:(The Effect of STEMA Approach on Creative Thinking Ability of 8th Grade Junior High School Students on Digestive System Material). *BIODIK*, *8*(2), 90-102. https://online-journal.unja.ac.id/biodik/article

Zubaidah, S. (2018). Mengenal 4C: Learning and innovation skills untuk menghadapi era revolusi industri 4.0. In *2nd Science Education National Conference* (Vol. 13, No. 2, pp. 1-18). Mengenal-4c-Learning-And-Innovation-Skills-Untuk-Menghadapi-Era-Revolusi-Industri-40-1.Pdf (Researchgate.Net)