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The Effectiveness of QR Scanner Smartphone Integrated Ecosystem-Based Material Modules in Fostering Problem-Solving Skills

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ABSTRACT

This study aims to evaluate the effectiveness of using the QR Scanner integrated teaching module in ecosystem material in improving students' problem-solving skills. The experimental method was involved in this study with a pretest-posttest control group design. The research subjects consisted of 60 students divided into two groups, namely the experimental group and the control group, each consisting of 30 respondents. The experimental group received a QR scanner smartphone integrated ecosystem-based material modules, while the control group did not receive specific intervention. Pretest and posttest data were collected from both groups to evaluate changes in problem-solving skills after the intervention. Data collection was carried out through tests and questionnaires. Research data was analyzed through paired t-tests to compare pretest and posttest values in each group. The results showed that the experimental group experienced a significant increase in problem-solving skills (p less than 0.001). In contrast, the control group did not show a significant difference (p better than 0.05). Thus, the QR Scanner integrated teaching module in ecosystem materials improved students' problem-solving skills. This research provides important implications for developing technology-based learning approaches to improve the quality of learning and the application of concepts in students' daily lives.

I. Introduction

The ability to solve problems is one of the critical aspects of learning that must be developed in students (Afandi et al., 2019; Ama & Emetarom, 2020; Andy, 2018; Rahman, 2019; Teo, 2019). With this ability, students can better face real-world challenges and become productive and creative individuals in various situations (Aslan, 2021; Gültekin & Altun, 2022; Valdez & Bungihan, 2019). Therefore, improving problem-solving abilities has become a primary focus of education. Problem-solving skills have a very important role in learning Natural Sciences (IPA) in Senior High Schools (SMA) (Fidan & Tuncel, 2019; Mahanal et al., 2019), including (i) Problem-solving skills help students better understand science concepts in a more in-depth way (Maknun, 2020; Ummah & Yuliati, 2020). When students learn to identify problems, formulate hypotheses, and seek solutions, they relate theoretical concepts to real situations so that their understanding becomes more concrete and relevant; (ii) Problem-solving requires creativity in finding new ways to overcome challenges (Ama & Emetarom, 2020; Teo, 2019). In science learning, students face complex problems and situations requiring innovative solutions. With good problem-solving skills, students can develop a creative mindset and become innovators in the scientific field. (iii) The problem-solving process involves in-depth analysis of existing information and data (Dowell et al., 2020; Nguyen et al., 2021).

Students learn to break down problems into smaller parts, identify patterns, and look for cause-and-effect relationships. This analytical ability is very relevant in science, where students are often faced with complex data that must be interpreted to reach conclusions; (iv) In science, students are often faced with situations where they must make decisions based on available evidence and data. Problem-solving skills help students to become intelligent decision-makers based on accurate information (González-Pérez & Ramírez-Montoya, 2022; Van Laar et al., 2020; Villanueva, 2022); (v) Good problem-solving skills become valuable assets for students when they face challenges in the real world (Al-Mutawah et al., 2019). Science is a constantly evolving and complex, and students with strong problem-solving skills will be better equipped to face future scientific and technological

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challenges. (vi) IPA aims to provide an understanding of the physical and natural world. With problem-solving skills, students can apply this knowledge in various situations in their daily lives and future careers and professions (Chew et al., 2019; Szabo et al., 2020).

Based on the theory above, problem-solving skills are central to developing students' understanding, creativity, analysis, and decision-making abilities in science learning. Thus, teaching and learning in SMA must support the development of these skills so that students can face future challenges with good competency.

However, the researchers' initial observations in the field showed that high school students' problem-solving skills were still low. Students are not able to identify and formulate the problem precisely. They have difficulty breaking down complex problems into smaller and coherent parts, which hinders their ability to find appropriate and practical solutions, for example, in ecosystem material. When tasked with analyzing changes in animal populations in an ecosystem experiencing environmental disturbances, most students only present raw data without conducting in-depth analysis or looking for alternative solutions. They find it challenging to identify the factors that cause population changes and are less able to link between the impact of environmental disturbances and the balance of the ecosystem.

In addition, when faced with case studies on ecosystem degradation and restoration efforts, some students rely on general or cliché solutions without considering the specific conditions and complexity of the problems encountered. Their lack of ability to identify alternative solutions that are more innovative and appropriate to specific ecosystem conditions makes their analysis less in-depth and less relevant. The low problem-solving skills of students in ecosystem material are also reflected when they are faced with situations in the field, such as conducting experiments to understand the interactions between organisms in an ecosystem. Some students have difficulty identifying variables that influence experimental results, collecting data correctly, or formulating appropriate conclusions based on the results obtained. This shows that their skills in planning and implementing steps to solve scientific problems are not yet skilled.

In conditions of low problem-solving skills, students often feel trapped and tend to experience frustration when faced with tasks or exercises that require deeper problem-solving (Lee & Lee, 2020; Mizyed & Eccles, 2023; Winkler et al., 2021). As a result, their interest in science may decrease, and they will lose confidence in dealing with more complex subject matter. To overcome students' low problem-solving skills, educators need to identify these obstacles and develop learning strategies, methods, and techniques that encourage the development of students' problem-solving skills (Li et al., 2023; Sinha, 2022). Thus, students will be better prepared to face real-world challenges and better develop their potential in natural sciences.

One alternative solution to address students' low problem-solving skills in science learning is ecosystem-based modules offering a holistic and integrated approach to teaching various concepts and skills (Molefe & Aubin, 2021; Nantha et al., 2022). In today's digital era, technology has become a powerful tool in the learning process. One of the technologies that continues to develop is the smartphone QR Scanner, which allows users to scan QR codes that can direct them to various digital information (AlNajdi, 2022; Ma et al., 2021; Savitri et al., 2021). This technology can be integrated into learning as an absorbing interactive medium to increase learning effectiveness.

Problem-solving skills in science education are crucial (Kiong et al., 2022; Topsakal et al., 2022). Problem-solving skills enable students to cultivate critical abilities in analyzing situations, identifying issues, and seeking practical solutions (Manuaba et al., 2022). Within science education, these skills aid students in comprehending and addressing scientific challenges, experiments, and research. When problem-solving skills are deficient, students may struggle to grasp complex scientific concepts and confront various scientific problems (Boran & Karakuş, 2022). Furthermore, the lack of problem-solving skills in science education can hinder the development of students' scientific competence, diminish their interest in science, and potentially limit their capacity to contribute to a society increasingly reliant on science and technology (Cheng et al., 2019 Jufrida et al., 2019). Therefore, emphasizing the development of problem-solving skills in science education is paramount in preparing a competent and skilled generation (Hurt et al., 2023; Price et al., 2022; Verawati et al., 2022).

Previous research has shown that the use of interactive teaching modules in learning can provide significant benefits in improving students' problem-solving skills (Halili, 2015; Ma et al., 2021; Molefe & Aubin, 2021; Nantha et al., 2022; Savitri et al., 2021). In this context, developing an ecosystem-based learning material module integrated with the smartphone QR Scanner has excellent potential to improve students' problem-solving skills. Some advantages of modules integrated with the smartphone QR Scanner include: (i) The use of the smartphone QR Scanner presents interesting interactive elements for students (Savitri et al., 2021). They can scan the QR code to access additional information, videos, images, or learning resources that support understanding of ecosystem material more engagingly; (ii) smartphone's QR Scanner allows students to get instant access to a broader range of information sources, such as articles, scientific journals, or up-to-date ecosystem data (Ma et al., 2021).

This helps students get a more comprehensive picture of the studied topic; (iii) smartphone QR Scanner integration enables teachers to present additional content visually and interactively (AlNajdi, 2022). For example, they can show documentaries about ecosystems, dynamic graphics, or interactive simulations that enrich students' understanding of complex science concepts; (iv) With the smartphone QR Scanner, students can be given direct problem-solving challenges related to ecosystem material (Savitri et al., 2021). They can be directed to complete field assignments, construct surveys, or analyze ecosystem data in real-time to improve their problem-solving skills; (v) The existence of smartphone QR Scanner technology in learning can increase student involvement (Ma et al., 2021). They feel more involved and active in the learning process because they can directly interact with existing content; and (vi) With a smartphone QR Scanner-based module, students can obtain additional information and understand ecosystem material independently (AlNajdi, 2022). They can choose the resources they want to access according to their learning needs, facilitating a student-centered learning approach. With the advantages above, the module integrated with the smartphone QR Scanner on ecosystem material in science learning is an effective and innovative tool for improving the quality of learning and students' problem-solving skills.

Several previous studies on QR Scanner QR-integrated teaching modules have been investigated; for example, nggraeni et al. (2022) developed a module integrated with a QR code to assist lecturers in delivering material to Physics Education Study Program students. This research does not explicitly focus on improving students' problem-solving skills but only on improving student learning outcomes. Lin & Teng, (2018) regarding using quick response (QR) codes to increase student participation in case-based learning. The focus of this research is to increase student participation in case learning, while our research focuses on improving problem-solving skills, so these two studies are different. Primandana also examines the effect of quick response (QR) on listening skills, while our research examines the effectiveness of the QR Scanner integrated teaching module to improve problem-solving skills.

Based on the background of the problems above and previous research, it is known that research is still very rarely conducted to test the effectiveness of the smartphone QR Scanner integrated teaching module to improve problem-solving skills. So, this study aims to fill this gap by evaluating the effectiveness of using the smartphone QR Scanner integrated with ecosystem-based learning material modules in helping develop students' problem-solving skills. This research will be conducted on SMA Batik 1 Surakarta class X students. It is hoped that the results of this study can provide a deeper understanding of the potential use of the smartphone QR Scanner technology and an ecosystem-based approach to improving students' problem-solving skills.

II. Method

The research approach used in this study was quasi-experimental with a pretest-posttest control group research design. This type of research aims to examine the effectiveness of the smartphone QR scanner integrated ecosystem-based learning module in improving problem-solving skills. The research subjects comprised 60 high school grade X students selected using a purposive sampling technique based on their initial problem-solving ability level. Each group consists of 30 students. Research subjects were selected based on inclusion criteria according to the research objectives. The research subjects were divided into two groups: the experimental group that would receive treatment (learning with an integrated ecosystem-based module on the smartphone QR scanner) and the control group that did not receive treatment (conventional learning).

Table 1. The research design is presented as follows:

Research Group	Research design	Measurement	Treatment
Experiment Group	Pretest → Intervention → Posttest	Problem-Solving Skills	HP QR Scanner Integrated Ecosystem-Based Module
Control Group	Pretest → No Treatment→ Posttest	Problem-Solving Skills	Conventional Learning

Table 1 shows that the experimental group received treatment in the form of learning using an ecosystem-based module integrated with the smartphone QR scanner, while the control group did not receive treatment and continued to follow conventional learning without using this module. Before treatment, both research subjects' problem-solving skills will be measured through the pretest. After that, the experimental group will receive an intervention, namely learning, using an ecosystem-based module integrated with the smartphone QR scanner. On the other hand, the control group did not experience additional treatment and continued to study as usual. After the intervention is completed, both groups will be measured again to evaluate the progress of their problem-solving skills through the posttest. The researchers carried out pretest and posttest measurements in both groups to compare the changes in problem-solving skills that occurred because of the treatment (learning with the smartphone QR scanner integrated ecosystem-based module) given to the experimental group compared to the control group, which did not receive the treatment.

Data collection techniques used tests that were tested on both research groups before and after the intervention. This test will measure students' problem-solving skills before and after using the smartphone QR scanner integrated ecosystem-based module. Data from the tests (pretest and posttest) will be analyzed using descriptive statistical techniques and inferential analysis, such as the t-test, to compare the scores between the experimental and control groups. The results of the data analysis will be used to conclude the effectiveness of the smartphone QR scanner integrated ecosystem-based learning module in improving problem-solving skills in students, as well as to provide recommendations for the development of subsequent learning.

III. Results and Discussion

Statistical descriptions of the experimental and control groups in the context of this study are presented in Table 2. This table presents statistical details of each observed variable, including pretest and posttest. Each group consists of 30 respondents who have participated in the program by integrating ecosystem-based learning modules equipped with a QR code scanner feature on mobile devices. The variables shown in this table include the average value (Mean), maximum value (Maximum), minimum value (Minimum), and standard deviation (Standard Deviation) for each group in the pretest and posttest phases.

Table 2. Statistical Description for Experimental and Control Groups (Pretest and Posttest)

Variable	N	Mean	Maximum	Minimum	Standard Deviation
Experiment Pretest	30	65.50	80	50	8.25
Posttest Experiment	30	85.60	95	60	9.12
Pretest Kontrol	30	63.40	80	48	7.92
Posttest Control	30	65.75	85	55	8.75

Table 2 shows that in the experimental group, 30 respondents participated in a learning program with ecosystem-based modules equipped with a QR code scanner feature on mobile devices. The analysis showed that the experimental group's average pretest score was 65.50, with the highest score reaching 80 and the lowest score reaching 50. After going through the learning program and taking the posttest, the average score increased to 85.60, with the highest score reaching 95 and the lowest score reaching 60. In addition, the standard deviation of the post-test score was 9.12, indicating the level of variation in the data in the experimental group.

Meanwhile, the 30 respondents' control group showed similar statistical results. In the pretest phase, the control group had an average score of 63.40, with a maximum score of 80 and a minimum score of 48. After the learning period and following the posttest, the average score increased to 65.75, with the highest score reaching 85 and the lowest value reaching 55. These results were also followed by a standard deviation of 8.75, which reflects the variation in the data in the control group.

From the results of this statistical description, we can see a difference between the pretest and posttest values in each group. In addition, the comparison between the experimental and control groups in the post-test phase also showed an interesting difference in average values for further analysis.

Furthermore, to ensure the validity of further analysis in this study, testing the normality of the data in each group is essential. This normality test aims to verify whether the data from each group is usually distributed. Normality testing will be done using the Shapiro-Wilk test on the pretest and posttest data for both experimental and control groups. If the p-value of this normality test is more significant than 0.05, it can be concluded that the data in the group are normally distributed. However, if the p-value is less than 0.05, then it is assumed that the data is not normally distributed, and some adjustments may be needed in the subsequent statistical analysis.

Table 3. Normality Values: Testing for normality using the Shapiro-Wilk test.

Group	Pretest	posttest
Experiment	0.723	0.736
Control	0.715	0.728

Table 3 contains the normality test results using the Shapiro-Wilk method on the pretest and posttest data for the two groups in this study. The average test results showed that in the experimental group, the p-value for the pretest data was 0.723, and for the post-test data was 0.736. In the control group, the p-value for pretest data was 0.715, and for post-test data was 0.728. In interpreting the normality test results, if the p-value is more significant than 0.05, then the data is considered normally distributed. In the table, the p values for both groups and each pretest and posttest are more significant than 0.05, so we can conclude that the experimental and control groups' data have a distribution that tends to be close to normal.

This close-to-normal data distribution has important implications for further statistical analysis. With normally distributed data, we can use various parametric statistical methods, such as the t-test, to test hypotheses and draw conclusions about the effectiveness of the implemented learning modules.

However, remember that these average test results are only one aspect of the data analysis process. Apart from normality, other aspects need to be evaluated in concluding the research results, including the homogeneity of the variance. By paying attention to all these aspects, the validity, and accuracy of research findings related to using the smartphone-integrated ecosystem-based Material Modules QR Scanner in improving students' problem-solving skills. Homogeneity test using the Levene test. The homogeneity test results are presented in Table 4.

Table 4. Homogeneity test results

Variable	Life Statistics	df1	df2	p-value
Pretest	0.472	1	58	0.495
posttest	0.389	1	58	0.536

Table 4 is the result of homogeneity testing using the Levene test on the pretest and posttest data for the two groups, namely the experimental group and the control group. The homogeneity test aims to check whether the variability or variance of the data within the groups is comparable or homogeneous. If the data variability between groups is homogeneous, then the assumption of homogeneity of variance is fulfilled, and the subsequent statistical analysis is reliable.

In the experimental group, the homogeneity test results showed that the Levene Statistical value for the pretest data was 0.472 with df1 (degrees of freedom in the numerator) of 1 and df2 (degrees of freedom in the denominator) of 58. In addition, the resulting p-value was 0.495. Likewise, for the experimental group's post-test data, the Levene Statistical value was 0.389 with a df1 of 1, a df2 of 58, and a p-value of 0.536. The two p-values in this homogeneity test are more significant than 0.05, which means that we fail to reject the null hypothesis; namely, the data variability in the experimental group's pretest and posttest is considered homogeneous.

Meanwhile, the homogeneity test results in the control group showed that the Levene Statistical value for the pretest data was 0.472 with a df1 of 1 and a df2 of 58. In addition, the resulting p-value was 0.495. Likewise, for the post-test data for the control group, the Levene Statistical value was 0.389 with a df1 of 1, a df2 of 58, and a p-value of 0.536. As in the experimental group, the two p-values in this homogeneity test were more significant than 0.05, which means that the data variability in the control group's pretest and posttest was considered homogeneous.

Thus, the results of the homogeneity test show that the two groups, namely the experimental group and the control group, have comparable or homogeneous data variability for each of the pretest and posttest variables. This ensures that the assumption of homogeneity of variance is met, and further statistical analysis can be performed more accurately and reliably.

With the homogeneity test results showing that the variance of the two groups' data is homogeneous, we can proceed to the next stage in data analysis, namely the paired t-test. Paired t-tests will be used to compare the differences between the experimental and control groups on the post-test variables. They will help us identify whether there are significant differences between the two groups after receiving intervention using the smartphone Integrated Ecosystem-Based Material Modules QR Scanner.

Table 5. T-test results

Variable	Mean Pretest	Mean Posttest	Average Difference	Standard Deviation	Uji t	p-value
Control Group	63.40	65.75	2.35	6.20	1.34	0.192
Experiment Group	65.50	85.60	20.10	9.12	4.30	<0.001*

Table 5 shows the results of the statistical t-test of 1.34 with a p-value of 0.192 for the control class. With a p-value more significant than the significance level (α) 0.05, there is no significant difference between the pretest and posttest values in the control group. In other words, the interventions provided did not produce significant changes in problem-solving skills in the control group. Meanwhile, the t-test results in pairs for the experimental class showed a statistical t-test value of 4.30 with a p-value of less than 0.001 (<0.001*). With a p-value lower than the significance level (α) of 0.05, there is a significant difference between the pretest and posttest values in the experimental group. This indicates that the intervention using the smartphone Integrated Ecosystem-Based Material Modules QR Scanner significantly improved problem-solving skills in the experimental group.

Thus, the results of this study indicate that the smartphone Integrated Ecosystem-Based Material Modules QR Scanner is efficacious in improving problem-solving skills in the experimental group compared to the control group, which did not receive the intervention.

The paired t-test results in this study showed a significant difference between the pretest and post-test values in the experimental group. However, they did not show a significant difference in the control group. This is confirmed by a significant value of 0.001 (smaller than 0.05). These results provide an interesting description of the effectiveness of the intervention using the smartphone Integrated Ecosystem-Based Material Modules QR Scanner in improving problem-solving skills in the experimental group compared to the control group.

Integrating QR code scanning technology on mobile devices allows easy and fast access to a wide range of supplementary learning materials, which can help improve students' understanding and application of concepts in problem-solving (Ali & Farhan, 2020; Ramalho et al., 2022). In the context of this study, interventions are expected to facilitate students' learning processes in ways that are more interesting, involving, and oriented toward practical application.

This study's results align with previous studies showing that the use of technology in learning, especially in the integration of application-based modules such as the QR Scanner, can positively impact by improving students' problem-solving skills. Several previous studies have found that the use of technology in learning approaches can increase learning motivation, active student interaction and improve understanding of concepts and their application in real-world situations (Ali & Farhan, 2020; Mogali et al., 2019; Ramalho et al., 2019, 2022).

Using QR Scanner integrated teaching modules in ecosystem materials has several advantages that can significantly improve students' problem-solving skills. Following are some of the advantages of this approach, including (i) Integrating QR Scanner technology in teaching modules provides a more interactive and exciting learning experience for students (Bers et al., 2019). Using a mobile device to scan the QR code, students can immediately access additional learning resources, videos, images, and other interactive content relevant to ecosystem materials. This interactive learning approach can increase students' interest in understanding ecosystem concepts more deeply; (ii) a QR Scanner allows students to access additional information related to ecosystem material easily (Srinounpan et al., 2020). These additional learning resources can come from various sources, such as e-books, scientific journals, educational websites, and learning videos. By having access to more complete and up-to-date information, students can develop a more comprehensive understanding of the ecosystem concept and its application in the context of everyday life; (iii) QR Scanner integrated teaching modules can be designed to facilitate problem-based learning (Nakamoto et al., 2020). Students can be given challenges or problem-solving assignments relevant to ecosystem material. Then, they can use the QR Scanner to find the correct information and solutions to solve the problem. This learning approach allows students to learn actively and practically, enhancing their problem-solving abilities; (iv) QR Scanner integration allows students to learn independently and flexibly outside the classroom (Mogali et al., 2019). Students can use their mobile devices to access additional learning content anytime and anywhere. The ability to study material independently allows students to adjust the time and pace of learning according to their individual needs and level of understanding; (v) QR Scanner technology can also be used to present augmented or simulated realities that allow students to visualize ecosystem concepts in a more accurate and immersive form (Uppot et al., 2019). For example, using the QR Scanner, students can access videos or animations depicting ecosystems and the interactions between organisms in their environment. This can help students to understand the concept of ecosystems more concretely and deeply.

Combining the advantages above, the QR Scanner integrated teaching module approach in ecosystem materials can help improve students' problem-solving skills effectively. Students' ability to access additional information, participate actively in learning, and visualize concepts more realistically can contribute to developing relevant and sustainable problem-solving skills (Savitri et al., 2021).

Overall, the t-test results in this study provide strong support for the effectiveness of using the smartphone Integrated Ecosystem-Based Material Modules QR Scanner in improving problem-solving skills in the experimental group. These results significantly contribute to developing technology-based learning approaches that can improve the quality and relevance of learning in education. This research has significant practical implications in the educational context. The research findings provide valuable insights into how technology, especially QR scanners and ecosystem-based modules integrated with mobile phones, can effectively enhance students' problem-solving skills. The practical implication is that this approach can be adopted in educational curriculum development to stimulate the development of students' problem-solving skills more efficiently. Educators may consider using QR scanner technology and ecosystem-based modules to provide a more engaging and practical learning experience. Furthermore, the research results underscore the importance of integrating technology into education, aligning with the trends in educational development in the digital era.

IV. Conclusion

The study concludes that integrating QR Scanner teaching modules in ecosystem materials effectively enhances students' problem-solving skills, as evidenced by a significant improvement in the experimental group's post-test scores. However, caution is advised in generalizing these findings due to the limited sample size and specific class environment. The study recommends future research with more extensive and diverse samples, exploring different intervention methods. It also suggests the integration of QR Scanners and similar learning technologies into school curricula to enhance student interest and problem-solving abilities. Teachers are encouraged to embrace innovative learning approaches, leveraging technology as an effective and engaging tool to enrich students' educational experiences.

References

Afandi, A., Sajidan, S., Akhyar, M., & Suryani, N. (2019). Development frameworks of the Indonesian partnership 21 st -century skills standards for prospective science teachers: A Delphi study. *Jurnal Pendidikan IPA Indonesia*, *8*(1), 89–100. https://-doi.org/10.15294/jpii.v8i1.11647

Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: High school graduates work analysis and standpoints. *International Journal of Education* *and Practice*, *7*(3), 258–273. https://doi.org/10.184-88/journal.61.2019.73.258.273

Ali, A. M., & Farhan, A. K. (2020). Enhancement of QR code capacity by encrypted lossless compression technology for verification of secure e-document. *IEEE Access*, *8*, 27448–27458. https://doi.org/10.11-09/ACCESS.2020.2971779

AlNajdi, S. M. (2022). The effectiveness of using augmented reality (AR) to enhance student performance: Using quick response (QR) codes in student textbooks in the Saudi education system. *Educational Technology Research and Development*, *70*(3), 1105–1124. https:-//doi.org/10.1007/s11423-022-10100-4

Ama, J. U., & Emetarom, U. G. (2020). Equipping higher education students with the 21st-century skills beyond computer and technological skills for future effective participation in the global economy. *European Journal of Education Studies*, *7*(5), 434–448. https://-doi.org/10.5281/zenodo.2588851

Andy, H. (2018). 21st century skills and the " 4Cs " in the English language classroom by Andy Halvorsen. In *American English Institute* (pp. 0–4).

Anggraeni, F. K. A., Prastowo, S. H. B., & Prihandono, T. (2022). Development of integrated QR code module on physics learning module to increase learning interest and know students' digital literacy. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2203–2209. https:-//doi.org/10.29303/jppipa.v8i5.1874

Aslan, A. (2021). Problem- based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers and Education*, *171*(May), 104237. https://doi.org/10.10-16/j.compedu.2021.104237

Bers, M. U., González-González, C., & Armas–Torres, M. B. (2019). Coding as a playground: Promoting positive learning experiences in childhood classrooms. *Computers and Education*, *138*, 130–145. https://doi.-org/10.1016/j.compedu.2019.04.013

Boran, M., & Karakuş, F. (2022). The mediator role of critical thinking disposition in the relationship between perceived problem-solving skills and metacognitive awareness of gifted and talented students. *Participatory Educational Research*, *9*(1), 61–72. https://doi.org/10.17275/per.22.4.9.1

Cheng, S. C., Hwang, G. J., & Chen, C. H. (2019). From reflective observation to active learning: A mobile experiential learning approach for environmental science education. *British Journal of Educational Technology*, *50*(5), 2251–2270. https://doi.org/10.-1111/bjet.12845

Chew, M. S. F., Shahrill, M., & Li, H. C. (2019). The integration of a problem-solving framework for Brunei high school mathematics curriculum in increasing student's affective competency. *Journal on Mathematics Education*, *10*(2), 215–228. https://-doi.org/10.22342/jme.10.2.7265.215-228

Dowell, N. M., Lin, Y., Godfrey, A., & Brooks, C. (2020). Exploring the relationship between emergent sociocognitive roles, collaborative problem-solving skills, and outcomes: A group communication analysis. *Journal of Learning Analytics*, *7*(1), 38–57. https://doi.org/10.18608/jla.2020.71.4

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers and Education*, *142*(May), 103635. https://doi.org/10.1016/j.compedu.2019.103-635

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of education 4.0 in 21st century skills frameworks: Systematic review. *Sustainability (Switzerland)*, *14*(3), 1–31. https://doi.org/10.3390/-su14031493

Gültekin, S. B., & Altun, T. (2022). Investigating the impact of activities based on scientific process skills on 4th-Grade students' problem-solving skills. *International Electronic Journal of Elementary Education*, *14*(4), 491–500. https://doi.org/10.26822/iejee.2022.258

Halili, S. H. (2015). Technological advancements in education 4.0. *The Online Journal of Distance Education and E-Learning*, *7*(1), 63–69.

Hurt, T., Greenwald, E., Allan, S., Cannady, M. A., Krakowski, A., Brodsky, L., & Dorph, R. (2023). The computational thinking for science (CT-S) framework: Operationalizing CT-S for K–12 science education researchers and educators. *International Journal of STEM Education*, *10*(1), 1–16. https://-doi.org/10.1186/s40594-022-00391-7

Jufrida, J., Basuki, F. R., Kurniawan, W., Pangestu, M. D., & Fitaloka, O. (2019). Scientific literacy and science learning achievement at junior high school. *International Journal of Evaluation and Research in Education*, *8*(4), 630–636. https://doi.org/10.11591/-ijere.v8i4.20312

Kiong, T. T., Rusly, N. S. M., Abd Hamid, R. I., Swaran, S. C. K., & Hanapi, Z. (2022). Inventive problem-solving in project-based learning on design and technology: A needs analysis for module development. *Asian Journal of University Education*, *18*(1), 271–278. https://doi.org/10.24191/ajue.v18i1.17196

Lee, B., & Lee, Y. (2020). A study examining the effects of a training program focused on problem-solving skills for young adults. *Thinking Skills and Creativity*, *37*(February), 100692. https://doi.org/10.1016/j.tsc.-2020.100692

Li, S., Pöysä-Tarhonen, J., & Häkkinen, P. (2023). Students' collaboration dispositions across diverse skills of collaborative problem solving in a computer-based assessment environment. *Computers in Human Behavior Reports*, *11*(November 2022), 100312. https://doi.org/10.1016/j.chbr.2023.100312

Lin, K. Y., & Teng, D. C. E. (2018). Using quick response codes to increase students' participation in case-based learning courses. *CIN - Computers Informatics Nursing*, *36*(11), 560–566. https://doi.org/10.1097/-CIN.0000000000000462

Ma, L., Mu, Y., Wei, L., & Wang, X. (2021). Practical application of QR Code electronic manuals in equipment management and training. *Frontiers in Public Health*, *9*(November), 1–6. https://doi.org/10.-3389/fpubh.2021.726063

Mahanal, S., Zubaidah, S., Sumiati, I. D., Sari, T. M., & Ismirawati, N. (2019). Ricorse: A learning model to develop critical thinking skills for students with different academic abilities. *International Journal of*

Instruction, *12*(2), 417–434. https://doi.org/10.29333/iji.2019.12227a

Maknun, J. (2020). Implementation of guided inquiry learning model to improve understanding physics concepts and critical thinking skill of vocational high school students. *International Education Studies*, *13*(6), 117–130. https://doi.org/10.5539/ies.v13n6p117

Manuaba, I. B. A. P., No, Y., & Wu, C. C. (2022). The effectiveness of problem based learning in improving critical thinking, problem-solving and self-directed learning in first-year medical students: A meta-analysis. *PLoS ONE*, *17*(11 November), 1–12. https://doi.org/10.1371/journal.pone.0277339

Mizyed, H. A., & Eccles, C. U. (2023). Understanding Emirati teachers' challenges in fostering problem-solving skills development in early years – A preliminary study. *Social Sciences and Humanities Open*, *8*(1), 100561. https://doi.org/10.1016/j.ssaho.2023.100561

Mogali, S. R., Vallabhajosyula, R., Ng, C. H., Lim, D., Ang, E. T., & Abrahams, P. (2019). Scan and learn: Quick response code enabled museum for mobile learning of anatomy and pathology. *Anatomical Sciences Education*, *12*(6), 664–672. https://doi.org/10.1002/ase.1848

Molefe, L., & Aubin, J. B. (2021). Pre-service teachers' views about ecosystem-based fieldwork in terms of the nature of environmental education, investigations, skills and processes. *Journal of Baltic Science Education*, *20*(4), 622–638. https://doi.org/10.33225/jbse/21.20.622

Nakamoto, I., Wang, S., Guo, Y., & Zhuang, W. (2020). A QR code-based contact tracing framework for sustainable containment of COVID-19: Evaluation of an approach to assist the return to normal activity. *JMIR MHealth and UHealth*, *8*(9), 1–11. https://doi.org/10.2196/22321

Nantha, C., Pimdee, P., & Sitthiworachart, J. (2022). A quasi-experimental evaluation of classes using traditional methods, problem-based learning, and flipped learning to enhance Thai student-teacher problem-solving skills and academic achievement. *International Journal of Emerging Technologies in Learning*, *17*(14), 20–38. https://doi.org/10.3991/ijet.v17i14.30903

Nguyen, T. H., Pham, X. L., & Thanh Tu, N. T. (2021). The impact of design thinking on problem solving and teamwork mindset in a flipped classroom. *Eurasian Journal of Educational Research*, *2021*(96), 30–50. https://doi.org/10.14689/ejer.2021.96.3

Price, A., Salehi, S., Burkholder, E., Kim, C., Isava, V., Flynn, M., & Wieman, C. (2022). An accurate and practical method for assessing science and engineering problem-solving expertise. *International Journal of Science Education*, *44*(13), 2061–2084. https://doi.org/10.1080/09500693.2022.2111668

Rahman, M. M. (2019). 21st century skill "problem-solving": defining the concept. *Asian Journal of Interdisciplinary Research*, *2*(1), 71–81.

Ramalho, J. F., Correia, S. F., Fu, L., António, L. L., Brites, C. D., André, P. S., & Carlos, L. D. (2019). Luminescence thermometry on the route of the mobile-based Internet of Things (IoT): How smart QR codes make it real. *Advanced Science*, *6*(19), 1–9. https://doi.org/10.1002/advs.201900950

Ramalho, J. F., Dias, L. M., Fu, L., Botas, A. M., Carlos, L. D., Carneiro-Neto, A. N., & Ferreira, R. A. (2022). customized luminescent multiplexed quick-response codes as reliable temperature mobile optical sensors for eHealth and the internet of things. *Advanced Photonics Research*, *3*(6), 2100206. https://doi.org/10.1002/adpr.202100206

Savitri, E. N., Amalia, A. V., Prabowo, S. A., Rahmadani, O. E. P., & Kholidah, A. (2021). The effectiveness of real science mask with qr code on students' problem-solving skills and scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *10*(2), 209–219. https://doi.org/10.15294/jpii.v10i2.29918

Sinha, T. (2022). Enriching problem-solving followed by instruction with explanatory accounts of emotions. *Journal of the Learning Sciences*, *31*(2), 151–198. https://doi.org/10.1080/10508406.2021.1964506

Srinounpan, B., Srinounpan, C., Sumethokul, P., & Patwary, A. (2020). The application of QR code technology to create the value-added products for the baan klong peek neur beehive community enterprise group at tambon suankhan, Nakhon Si Thammarat Province. *Systematic Reviews in Pharmacy*, *11*(7), 519–528. https://doi.org/10.31838/srp.2020.7.76

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability (Switzerland)*, *12*(23), 1–28. https://doi.org/10.3390/su122310113

Teo, P. (2019). Teaching for the 21st century: A case for dialogic pedagogy. *Learning, Culture and Social Interaction*, *21*(January), 170–178. https://doi.org/10.1016/j.lcsi.2019.03.009

Topsakal, İ., Yalçın, S. A., & Çakır, Z. (2022). The effect of problem-based stem education on the student's critical thinking tendencies and their perceptions for problem-solving skills. *Science Education International*, *33*(2), 136–145. https://doi.org/10.33828/sei.v33.i2.1

Ummah, I. K., & Yuliati, N. (2020). The effect of jumping task based on creative problem solving on students' problem solving ability. *International Journal of Instruction*, *13*(1), 387–406. https://doi.org/10.29333/iji.2020.13126a

Uppot, R. N., Laguna, B., McCarthy, C. J., De Novi, G., Phelps, A., Siegel, E., & Courtier, J. (2019). Implementing virtual and augmented reality tools for radiology education and training, communication, and clinical care. *Radiology*, *291*(3), 570–580. https://doi.org/10.1148/radiol.2019182210

Valdez, J. E., & Bungihan, M. E. (2019). Problem-based learning approach enhances the problem solving skills in chemistry of high school students. *Journal of Technology and Science Education*, *9*(3), 282–294. https://doi.org/10.3926/JOTSE.631

Van Laar, E., Van Deursen, A. J., Van Dijk, J. A., & de Haan, J. (2020). Determinants of 21st-century skills and 21st-century digital skills for workers: A systematic literature review. *SAGE Open*, *10*(1). https://doi.org/10.1177/2158244019900176

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ISSN: 0215-9643
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Verawati, A., Agustito, D., Pusporini, W., Utami, W. B., & Widodo, S. A. (2022). Designing Android learning media to improve problem-solving skills of ratio. *Advances in Mobile Learning Educational Research*, *2*(1), 216–224. https://doi.org/10.25082/amler.2022.01.005

Villanueva, J. M. (2022). Language profile, metacognitive reading strategies, and reading comprehension performance among college students. *Cogent Education*, *9*(1), 1–19. https://doi.org/10.1080/2331186X.2022.2061683

Winkler, R., Söllner, M., & Leimeister, J. M. (2021). Enhancing problem-solving skills with smart personal assistant technology. *Computers and Education*, *165*(August 2020). https://doi.org/10.1016/j.compedu.2021.104148