

Citizen science project (CSP) learning model as innovation learning in improving 21st century skills

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Article Information	Abstract
Keywords: 21st century; Citizen science project; Learning innovation; Learning model Kata kunci: Abad 21; Citizen science project; Inovasi pembelajaran; Model pembelajaran History: Received : 24/10/2024 Revised : 13/01/2025 Accepted : 20/01/2025 Published : 30/01/2025	Learning models that are in line with the challenges of the 21st century, namely involving students to think critically, creatively, and be able to communicate and collaborate are very important to develop. One of the learning models that support this is the Citizen Science Project (CSP) model. This research uses the development method with the ADDIE approach, which consists of the analysis stage, design stage, development stage, implementation stage, and evaluation stage. The CSP learning model consists of syntax, reaction principles, social systems, support systems, and instructional and accompanying impacts. The focus of this research is up to the implementation stage, which involves analysing the validation of the CSP model as well as the practicality test by teachers and learners. The instruments used in the study included a validation questionnaire for two expert validators, as well as a practicality questionnaire for 2 teachers and 34 learners. The data were analysed based on the feasibility of the CSP model, as assessed by the validators, as well as practicality from the perspective of teachers and learners. The validation results showed an average score of 4.38 out of 5, which falls into the valid category. Practicality assessment by learners resulted in a score of 83.2 which is included in the very practical category, while teachers gave a score of 84.8 which is also included in the very valid category. Based on these results, it can be concluded that the CSP learning model is valid and very practical to be applied to support 21st century learning in improving 4C skills. <i>Abstrak. Model pembelajaran yang selaras dengan tantangan abad ke-21, yaitu melibatkan siswa untuk berpikir kritis, kreatif, serta mampu berkomunikasi dan berkolaborasi, sangat penting untuk dikembangkan. Salah satu model pembelajaran yang mendukung hal ini adalah model Citizen Science Project (CSP). Penelitian ini menggunakan metode pengembangan dengan pendekatan ADDIE, yang terdiri dari tahap analisis, tahap desain, tahap pengembangan, tahap implementasi, dan tahap evaluasi. Model pembelajaran CSP terdiri atas sintaks, prinsip reaksi, sistem sosial, sistem pendukung, serta dampak instruksional dan dampak penyerta. Fokus penelitian ini hingga tahap implementasi, yang melibatkan analisis validasi model CSP serta uji kepraktisan oleh guru dan peserta didik. Instrumen yang digunakan dalam penelitian ini mencakup kuesioner validasi untuk dua validator ahli, serta kuesioner kepraktisan untuk dua guru dan 34 peserta didik. Data dianalisis berdasarkan kelayakan model CSP yang dinilai oleh validator, serta kepraktisannya dari perspektif guru dan peserta didik. Hasil validasi menunjukkan skor rata-rata 4,38 dari 5, yang termasuk dalam kategori valid. Penilaian kepraktisan oleh peserta didik menghasilkan skor 83,2, yang termasuk dalam kategori sangat praktis, sedangkan guru memberikan skor 84,8, yang juga termasuk dalam kategori sangat valid. Berdasarkan hasil tersebut, dapat disimpulkan bahwa model pembelajaran CSP valid dan sangat praktis untuk diterapkan guna mendukung pembelajaran abad ke-21 dalam meningkatkan keterampilan 4C.</i>

A. Introduction

Education is a form of conscious and planned effort that aims to prepare students through guidance and teaching carried out by a teacher (Arraniri et al., 2021). Education is one of the most important aspects of life as an empowerment effort to face global challenges. Through education, students can develop potential, intelligence, skills, personality and noble character that can be formed and directed.

Science and technology are developing rapidly in line with the era of globalisation and the times in the 21st century, which is known as the period of knowledge or learning new things so that the quality of education must be improved (Stuchlikova, 2016; Septikasari & Frasandy, 2018; Muhali, 2019). Education can be improved by implementing 21st century learning, defined as learning that can provide 21st century skills for students (Munawwarah et al., 2020; Zainil et al., 2023). These skills include communication, collaboration, critical thinking problem solving, and creative and innovative, known as the 4Cs (Adnan et al., 2021)

The new paradigm of education today, learning objectives are not only focused on developing knowledge (Sukmawati et al., 2022), but must be oriented so that students have critical, creative, communicative abilities as well as character. This is in line with the opinion expressed by Adnan et al. (2021) stating that the existence and importance of 4C as a high-level skill is proven in empirical results.

In reality, the learning environment still focuses on the teacher as an educator, causing boredom for students. Learning methods and models that overemphasise one-way learning often result in a lack of learner engagement. Learners do not have the opportunity to actively participate or apply 4C knowledge (Warsah et al., 2021; Zubaidah, 2016) as a result their motivation decreases and the learning experience is monotonous. According to Filmi et al (2024), learning models are a means to improve learning objectives and learning productivity.

Based on observations that have been made, Rappocini High School still applies learning with the lecture method. The lecture method does not provide opportunities for learners to develop skills 4C, even though these skills are very important for the cognitive development of learners (Rahayu et al., 2022). In line with that, the low learning outcomes of students at the secondary school level, still relying on teacher-centred learning methods include 53%, 20% project learning and 5% involving class discussions and the lack of use of technology in teaching (Sumardi et al., 2020). This is due to the lack of teaching materials, teacher interaction and the lack of use of innovative and interesting learning methods (Adnan et al., 2012; Adnan et al., 2014; Aldi et al., 2022). The implication of this condition is that students in Indonesia lag behind other countries in

the aspects of critical thinking, collaboration and technology.

Teachers must be the most important part in developing 21st century skills. Of course, in this case teachers must have good content knowledge, curriculum knowledge and pedagogical content to be able to carry out various learning processes (Moreira et al., 2023). Efforts made by teachers to integrate the skills needed for the 21st century can be through learning (classroom and neighbourhood). Based on previous research, there is learning that can improve 21st century skills, namely using Citizen Science Project (CSP)

Citizen science (CS) is a concept that allows the public to collaborate with professional scientists in the collection and analysis of data related to the natural environment. This concept not only opens up opportunities for the public to be directly involved in scientific research, but also provides a platform for dynamic interactions between the public and scientists and can increase participants (Stein & Yazdanpanah, 2023). According to Bonney et al. (2016) in their research, they found convincing evidence that the scientific results of participatory CS are well recorded, especially in data collection and processing projects. CS is integrated into CSP, an active participatory learning involving learner project contributors (community and experts) (Paige et al., 2015; Muaziyah et al., 2023).

In Indonesia, learning using CSP is still very little, even though the education system in the European Union and the United States has made CSP an important part of the education system and is considered to be able to confront science learning and education (Aripin et al., 2023). In addition, curriculum demands also expect students to be able to carry out project learning; students become stakeholders and have challenges in solving problems that are relevant to their lives (Sukmawati et al., 2022).

Research on CSP is still primarily focused on its implementation as a learning approach (Sahira et al., 2023). Therefore, this research introduces an innovative CSP learning model in the field of education, which is highly relevant to previous studies, aligns with 21st century learning needs, and addresses teachers' concerns in selecting a model that fosters 4C skills (Sahira et al., 2023; Adnan et al., 2024).

B. Material and method

This research uses the R&D (Research and Development) method with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) research approach (Rustandi, 2021), which aims to produce a product through certain steps. The focus of this research is only limited to the implementation stage; researchers have not tested the effectiveness or

evaluation. This research aims to produce a valid and practical learning model.

Product validation is important to find out the weaknesses or shortcomings developed (Rahman et al., 2020). The validity test was identified through the application of a research instrument in the form of a questionnaire given to two expert validators, namely material experts and media experts. Two validators such as media experts and material experts are adequate in the development process, because both validators cover technical aspects and substance. The media expert focuses on the design and presentation aspects of the media, while the material expert ensures the content is accurate and relevant.

Hafiza et al. (2022) and Syam & Izzati (2020) in their research stated that media and material expert validators are adequate because both provide criteria in ensuring learning media have high validity. The assessment is carried out using the checklist (✓) method in the assessment column with qualitative categories can be seen in Table 1.

Table 1 Valid categories

Value	Qualitative categories
$V_a = 5$	Very valid
$4 \leq V_a < 5$	Valid
$3 \leq V_a < 4$	Less valid
$2 \leq V_a < 3$	Invalid
$1 \leq V_a < 2$	Very invalid

(Source: Hobri, 2010)

The instrument validity test conducted by the two validators obtained a result of 4.66 which is at the interval value of $4.00 \leq V_a < 5.00$, and is classified as valid. After the validity test on the instrument and validity test on the model, then the practicality test of the CSP learning model was carried out on 38 grade X students and 2 grade X teachers. Qualitative practicality categories can be seen in Table 2. The limits of this practicality category are in the qualitative categories of practical and very practical.

Table 2 Practical categories

Value	Qualitative categories
$81 \leq R < 100$	Very practical
$61 \leq R < 80$	Practical
$41 \leq R < 60$	Less practical
$21 \leq R < 40$	Not practical
$0 \leq R < 21$	Not very practical

C. Results and discussion

The learning model is a conceptual framework that is systematically arranged to facilitate interaction, solve problems, achieve optimal goals, and encourage teachers to design maximum learning practices (Jayawardana & Djukri, 2015; Filmi et al., 2024).

The independent curriculum in biology learning that is analyzed involves an assessment of

the problems in learning that are faced, such as the relevance of material, learning models, learning motivation, learning conditions, and student learning outcomes. The development of the learning model is based on the study of phase E and phase F learning outcomes, learning objectives and indicators contained in the content standards in the independent curriculum. The results of the learning model analysis show that using the lecture method by some teachers causes boredom in learning so some students lose focus and look for other activities.

The results of observations and interviews found that teachers and students need a learning model that can train students' critical and creative thinking skills as well as increase motivation, collaboration, and environmental problem-solving and require a variety of learning (Rahayu et al., 2022; Adnyana & Sudaryati, 2022) which then facilitates understanding of concepts and attracts students' interest in learning in achieving learning objectives.

Researchers formulated learning objectives and competencies achieved at the design stage. This aims to limit researchers so as not to deviate from the development objectives. Furthermore, researchers compiled several project design plans, including developing CSP teaching modules by the phase E independent curriculum, compiling materials and examples of project implementation on biodiversity material (interview guides, consultation guides, data collection instruments, examples of project reports), then compiling toolkits (CSP devices) that would support the implementation of student projects, toolkits consisted of (project theme, project description, project objectives, tools and materials, project methods, location planning, resources, and expected results). Ramanda et al. (2023) stated that interesting learning media will support the learning process.

To support the implementation of the CSP learning model, researchers developed the Biozen project web to collect and obtain information related to the project. The Biozen project web consists of several features, including learning (projects and live teaching), science projects (location projects, upload projects, and our projects), surveys, consultants, media, and about. Adnyana & Sudaryati (2022) stated that the learning model accompanied by blended (web) can support literacy, adequate competence, strong character, and sensitivity to the environment.

The development of the CSP learning model was designed at an early stage to support improving the quality of 21st-century learning. The CSP-based learning approach (previous research) became the CSP learning model. The result of this development stage is a CSP learning model that has been structured by the independent curriculum.

The syntax of the developed CSP learning model can be seen in Table 3.

Table 3 Syntax of the CSP learning model

Stage	Teacher, learner activities, expert consultation
Project problem orientation	The teacher presents the learning objective of identifying a relevant problem for the project. Learners are invited to discuss in groups to understand the experimental question they will solve and engage experts online to provide motivation.
Plan making project	The teacher provides a project toolkit. With this toolkit, learners discuss in groups to determine their project plan. The project plan is then submitted to the teacher for feedback and approval. Online expert consultation to ensure the project plan is realistic.
Timeline creation	The teacher guides learners in developing a realistic and structured timeline (covering each activity). Learners discuss this timeline in their groups and adjust it if needed. An online expert consultation ensures the timeline is optimal.
Project implementation	The teacher organizes and monitors the implementation of project activities, both in the field and in the laboratory, and ensures that all necessary tools and materials are available and ready to use. Learners carry out project activities (observation and data collection) by involving the community according to predetermined methods and record the results of observations and interviews. Learners receive assistance from volunteers in project implementation.
Project monitoring	Teachers hold regular meetings to monitor the project's progress and provide feedback to overcome obstacles that learners face during the project. Learners report their project progress regularly and discuss in groups to solve problems encountered during project implementation.
Project monitoring	Teachers provide clear assessment rubrics and give constructive feedback to learners. Learners compile a final project report and then present their project results to the class.
Project evaluation	The teacher organizes a discussion session to evaluate the project's success and correct any shortcomings. Learners write personal reflections on the experiences and lessons learned from the project and discuss them in groups to evaluate the project's success. Online expert consultation to provide additional guidance in this evaluation process.

Innovation in learning is realized through a project-based learning model through the structured stages in Table. 3, which empowers learners' critical and creative thinking skills (Aripin et al., 2023; Adnan et al., 2024). This learning model is applied face-to-face (offline) and online. In the CSP learning model, learners learn in groups to collect data or information to solve scientific problems in related subjects (Fujiwara et al., 2019; Abourashed et al., 2021; Adnan et al., 2024).

The CSP learning model not only helps improve learners' engagement in scientific research learning but also helps in developing data analysis, presentation, and collaboration (Phillips et al., 2018), which are important parts of learning biology. In addition, learners can develop a deep understanding of biological concepts and gain real-world experience with teacher guidance, expert support, and the help of a community of experts (scientists) (von Konrat et al., 2018). In addition to syntax, the CSP learning model also consists of reaction principles, social systems, and support systems, and the impact of CSP learning models summarised in the CSP learning model resume can be seen in Figure 1.

The CSP learning model resume, shown in Figure 1, consists of syntax, reaction principles, social systems, and support systems, and the impact of the CSP model consisting of instructional impact and accompanying impact, which refers to the positive impact of both pedagogical, social and technological aspects. The reaction principle of the CSP learning model involves teachers influencing learners' learning experience and encourages learners' active involvement in group learning. According to

Kelemen-Finan et al. (2018), the relationship between teachers and learners plays a crucial role in determining the quality of teaching and learning, with each phase of the CSP model serving as the foundation for their interaction in the classroom.

The social system of the CSP learning model supports effective collaboration and communication between teachers, learners, and experts in project activities. The social component of CSP learning consists of group discussion, class discussion, expert involvement, field collaboration, reflection forum, assessment panel, feedback, class reflection, and report evaluation (Adnan et al., 2024). Through the interview process, the collaborative methods used to play an important role in integrating observation and inquiry in decision-making (Senabre et al., 2018; Bonney et al., 2016).

The CSP learning model includes a supporting system to support the implementation of learning. These support systems include digital platforms, learning resources, physical infrastructure, evaluation and assessment, communication and collaboration, logistical support, reflection, and development (Adnan et al., 2024). A learning support system that can be used anywhere effectively will improve academic achievement and encourage positive views of its users (Thongkoo et al., 2019).

The instructional impact of CSP is to assist learners in understanding the material in-depth and mastering cognitive, affective, and psychomotor skills. The accompanying impact of this model is enriching learners' learning experiences and positive attitudes towards the environment support learners' personal and social development. CSP can foster

good attitudes towards environmental management, and encouragement to project participants in environmental data collection will increase environmental awareness (McKinley et al., 2017).

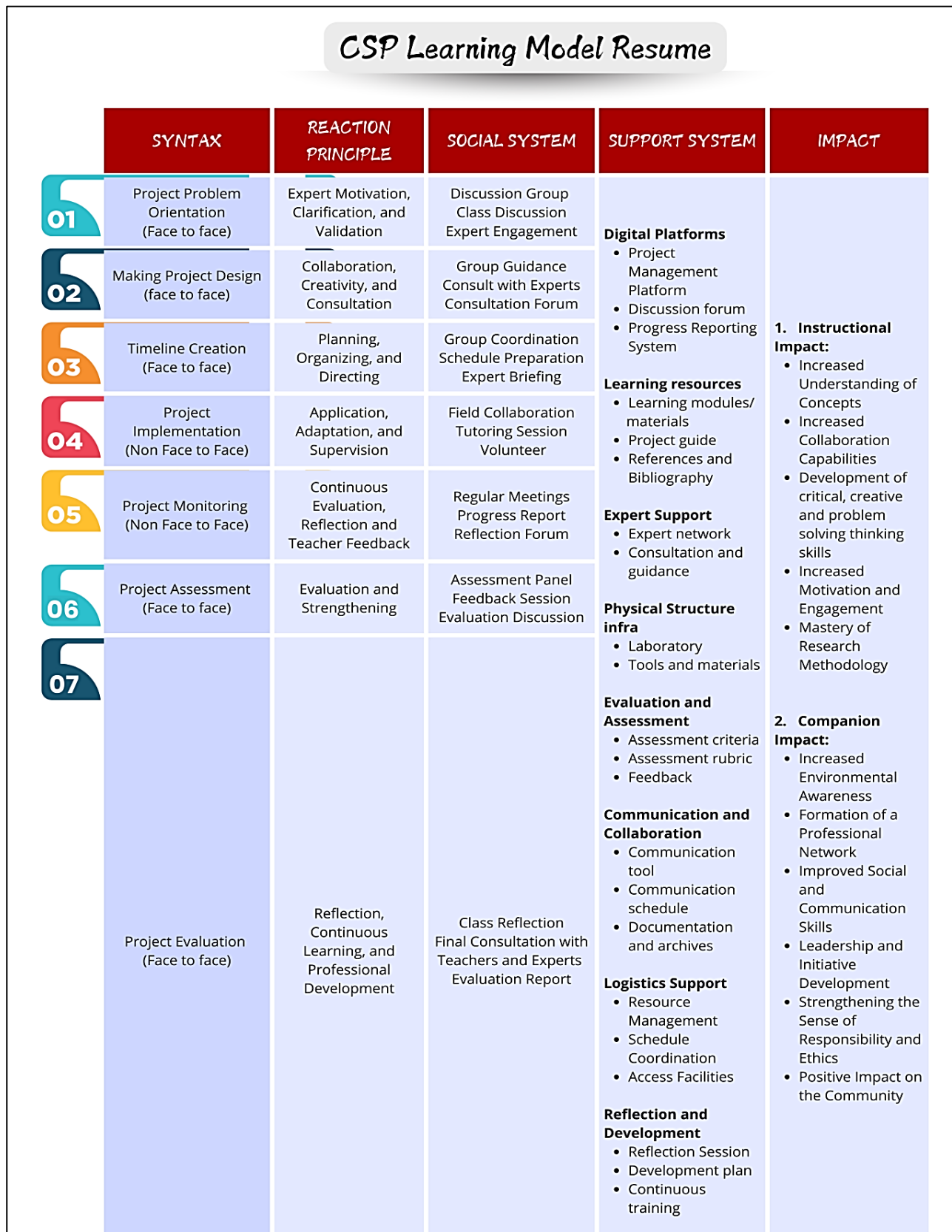


Figure 1 CSP learning model resume (Source: Adnan et al., 2024)

Table 4 Validation test results

No.	Assessment Aspect	Average	Category
1.	Syntax aspect of learning model	4.53	Valid
2.	Aspect Reaction Principle	4.50	Valid
3.	Social System Aspects	4.58	Valid
4.	Support System Aspects	4.12	Valid
5.	Aspects of Instructional Impact and Companion Impact	4.22	Valid
6.	Aspects of 21st-century characteristics	4.36	Valid
Average		4.38	Valid

One of the stages of development is conducting validity tests with two expert validators consisting of material expert validators and media experts on the CSP learning model that has been developed before being applied to learning. The results of the recapitulation of the feasibility test of CSP learning model expert validators can be seen in Table 4.

Based on the results of the validation of the CSP model, the average accumulated value of each aspect of the assessment shows a value of 4.38, at the interval value of $4.00 \leq Va < 5.00$, which is in the valid criteria (good degree of validity). The CSP learning model developed is also feasible, both from the aspects of learning syntax, aspects of the reaction principle, aspects of the social system, aspects of the support system and instructional impact and accompanying impact, as well as aspects of 21st century characteristics. Reliability and validity are important aspects in determining the right measure for a construct because they play a role in assessing the measure's effectiveness to meet most of the established quality criteria and assessing the measure's effectiveness (Elvionita & Fauzi, 2019; Kamper, 2019).

The validated CSP learning model is implemented on biodiversity material in class X, which consists of 3 projects. The first project is the biodiversity project, which includes the diversity of genes, species, ecosystems, determination and dichotomous keys, and classification of living things. The next project is the lost project (the disappearance of biodiversity), and the last project is the preservation project (efforts to preserve biodiversity). Biodiversity is an interesting learning concept from a scientific point of view and has social value in various subjects (Echeverria et al., 2021). In their research, Peter et al. (2019), stated that biodiversity data collection is the existence of taxonomic groups (species, genus, family), genetics, and functions that can be identified through information collection or observation.

The implementation of the project went very well although there were still obstacles such as not matching the project schedule with the project implementation agenda, due to the many school activities of the students. However, students in each group have carried out project activities well, as can be seen in Figure 2.

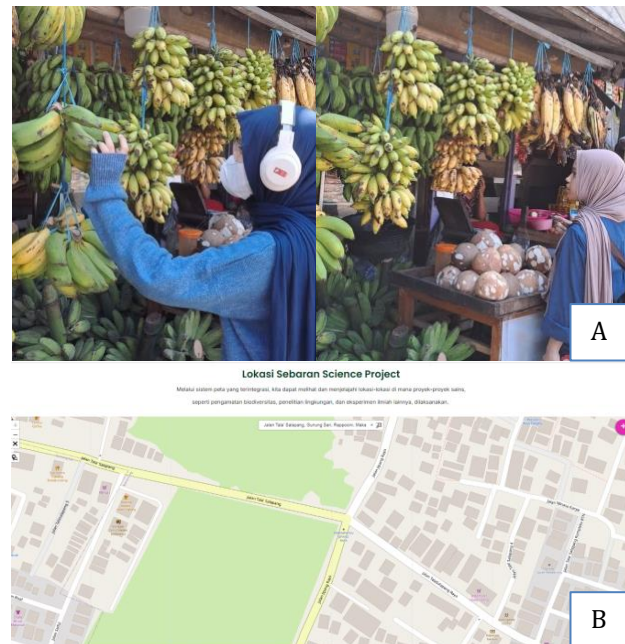


Figure 2
(A) Observation of gene diversity in banana fruit (*Musa paradisiaca*) at tallasalapang market, and (B) location of gene diversity project implementation distribution

These observations were made through observations and interviews. McKinley et al. (2017) said CSP is well suited for interdisciplinary collaboration, especially for environmental and social projects. The results of the observations are then discussed in group teams and interim reports, as well as final reports. The final results of the learning meeting will be collected on the biozen project web, which can be seen in Figure 3.



Figure 3 Main view of Biozen project web

Table 5 Results of practicality test for learners

Indicators	Average	%R
Curriculum and learning outcomes	4.21	84.2
Reaction principle	4.12	82.4
Social system	4.34	86.8
Support system	4.03	80.6
4c skills	4.13	82.6
Average	4.16	83.2

Table 6 Teacher practicality test results

Indicators	Average	%R
Curriculum and learning outcomes.	4.25	85.0
Reaction principle	4.16	83.2
Social system	4.54	90.8
Support system	4.09	81.8
4c skills	4.19	83.8
Average	4.24	84.8

Knowledge is transferred between teachers and technology through collaboration that supports learner learning. Technology helps create environments that facilitate interactions between novice and experienced learners, guide professional development and knowledge creation by collaboration between experts and novices, and increase the value of field activities in various learning environments (Echeverria et al., 2021). Vicens et al. (2018) in their research mentioned that the platform records all actions performed by participants and provides surveys to collect data and their decision-making process.

Learners submit the final project report on time because there is a collection time range on the Biozen project web, so CSP-based learning is effectively implemented. The results of the practicality of students' responses to the CSP learning model can be seen in Table 5. Based on the practicality results in students, the CSP learning model is in the interval $81 \leq R < 100$, which is in very practical criteria. This is due to learning activities with this model, helping students in active learning through research skills (Damayanti et al., 2021) so that it is easier to absorb material through simulation and development of students' critical thinking skills (Agnafia, 2019; Aripin et al., 2021; Amaliah et al., 2022). The design of learning projects encourages active learner involvement and has proven effective in achieving learning objectives (Lüsse et al., 2020). In line with that, research conducted by Almunawarah et al. (2023) stated that providing thought challenges or project tasks will encourage learners to investigate problems more deeply and perform problem-solving with critical thinking skills.

Learners' activeness through collaborative activities also contributes to the success of the CSP learning model. Learners conduct group discussions, seek guidance from teachers and volunteers, interview and observe projects, and consult experts. According to Adnan et al. (2024), three main

principles of collaboration, creativity and consultation play a crucial role in ensuring the success of the project and the development of learners' skills. Teamwork facilitates project-based learning with the help of technology proven to create an engaging learning experience.

In addition to the learners' response, there is also a teacher's practicality response, which can be seen in Table 6. Based on the results of teacher practicality in Table 6 shows that the CSP learning model is in the interval $81 \leq R < 100$, which means it is in very practical criteria. This is because the CSP learning model supports the curriculum and learning outcomes related to biology subjects with a practicality percentage of 83.2. In addition, the social indicator obtained a very high percentage of practicality of 90.8 because the CSP learning model involves experts, communities and group collaboration. However, involving external scientists and communities is still classified as ineffective, this is because the scope of project observations is still up to the school environment and the home environment of students who have not reached the participation of scientists and communities. Adnan et al. (2024), and He & Wiggins (2017) mentioned that the CSP learning environment is designed to encourage active participation of learners from both pedagogical, social and technological aspects.

The lowest average on the project indicator is the support system for the implementation of the CSP learning model, especially the use of the internet on the Biozen project web platform, which makes it difficult to access the project location and submit the students' final report. Focusing on interactive learning, social collaboration, and good and appropriate use of technology will support developing knowledge independently and meaningfully through problem-solving (Hujatusnaini et al., 2022). CSP learning will be effective if all school components support learners' project steps by providing appropriate guidance.

D. Conclusion

Based on the results of the recapitulation of the validation feasibility test and the practicality of the CSP learning model, the results of the accumulation of the average assessment aspects with a value of 4.38 with a valid category and the practicality of students and teachers each in the interval $81 \leq R < 100$ with a very practical category. It can be concluded that the CSP learning model has a distinctive feature in syntax stages, which involve the participation of volunteers and the community in the learning process. This participation is an important element that supports project implementation and enriches learners' learning experience through collaboration and real contribution in finding solutions to project problem orientation. In addition, the developed CSP learning model can improve the quality of learning in the independent curriculum and 21st-century challenges because the implementation of CSP-based learning is carried out not only learning about science concepts but also by applying scientific methods in real situations that can help improve learners' knowledge, critical thinking, collaboration, and communication skills, as well as awareness of problems in the community environment.

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