



Pengaruh Research-Based Project (RBP) pada Mata Kuliah Fisiologi Tumbuhan Terhadap Meta-skills Mahasiswa

The Impact of Research-Based Projects (RBP) in Plant Physiology Course on Undergraduate Student Meta-skills

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Abstrak

Penguasaan *meta-skills* penting bagi mahasiswa untuk mempersiapkan diri dalam menghadapi perubahan dunia yang sangat cepat akibat kemajuan ilmu pengetahuan dan teknologi. Oleh sebab itu, penelitian ini bertujuan untuk mengetahui dampak penerapan *research-based project* (RBP) pada mata kuliah fisiologi tumbuhan terhadap *meta-skills* mahasiswa. Studi ini merupakan penelitian *quasi-experiment* dengan rancangan *non-equivalent pre-test post-test control group design*. Sampel penelitian adalah mahasiswa pendidikan biologi Universitas Bengkulu yang dipilih berdasarkan teknik *purposive sampling*. Teknik pengumpulan data menggunakan angket yang terdiri dari 79 item pernyataan dan data hasil penelitian dianalisis menggunakan uji One-Way ANCOVA. Hasil penelitian menunjukkan bahwa terdapat perbedaan signifikan *meta-skills* antara kelas kontrol dan kelas eksperimen dengan mengontrol *meta-skills* awal mahasiswa [$F(1, 61) = 313.996$; $p < 0.001$; $\eta_p^2 = 0.84$]. Berdasarkan hasil tersebut, dapat disimpulkan bahwa penerapan model *research-based project* (RBP) berpengaruh besar atau sangat efektif dalam meningkatkan *meta-skills* mahasiswa.

Kata kunci: Fisiologi Tumbuhan; *Meta-skills*; *Quasi-Experiment*; *Research-Based Project* (RBP)

Abstract

Mastery of *meta-skills* is essential for undergraduate students to prepare themselves for the rapidly changing world driven by advancements in science and technology. Therefore, this study aims to investigate the impact of implementing the *research-based project* (RBP) model in a plant physiology course on undergraduate students' *meta-skills*. This study employed a *quasi-experimental design* with a *non-equivalent pre-test and post-test control group design*. The research sample consisted of biology education students at the University of Bengkulu selected through *purposive sampling*. Data were collected using a questionnaire consisting of 79 items, and the research data were analyzed using a *One-Way ANCOVA* test. The results showed a significant difference in *meta-skills* between the control and experimental groups, controlling for students' initial *meta-skills* [$F(1, 61) = 313.996$; $p < 0.001$, $\eta_p^2 = 0.84$]. Based on these findings, it can be concluded that the implementation of the *research-based project* (RBP) model has a substantial or highly effective impact on enhancing undergraduate students' *meta-skills*.

Keywords: *Meta-skills*; *Plant Physiology*; *Quasi-Experiment*; *Research-Based Project* (RBP)

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INTRODUCTION

The rapid development of science and technology has significantly impacted various aspects of life. Many jobs have disappeared, while new types of jobs have emerged. Research reports indicate that 65% of today's learners will work in jobs that do not yet exist. Higher

education needs to respond to this by equipping students with a variety of skills so that they can adapt and thrive in the face of rapid and unpredictable changes.

One of the skills that supports individuals' adaptability to change is meta-skills (Astriawati & Mardiyanti, 2023). According to The Scottish Funding Council (2019) and Skills Development Scotland (2018), meta-skills are high-level skills that stimulate individuals' adaptability, enabling them to perform effectively in a constantly changing work environment and driving success in any context. Meta-skills encourage individuals to continuously learn, actively engage in problem-solving, and continually develop new competencies, thereby leading to lifelong learning that helps individuals prepare for future changes (Prasittichok & Klaykaew, 2022; Senova, 2020).

An individual is considered to possess proficient meta-skills when demonstrating strong self-management, social intelligence, and innovation capabilities (Skills Development Scotland, 2018, 2021). These competencies enable individuals to adapt to a continuously evolving environment by embracing new ideas, exhibiting cognitive flexibility, and maintaining a commitment to lifelong learning and skill development (Mandro, 2022). Fundamentally, meta-skills are intrinsic abilities that individuals utilize to explore their surroundings and serve as the foundation for developing additional technical and transferable competencies (Astriawati & Mardiyanti, 2023; Barkas et al., 2021). As individuals pursue higher education, educational practitioners must cultivate and enhance their students' meta-skills to prepare them for an increasingly complex and unpredictable world. Consequently, higher education practitioners need to prioritize the development of their students' meta-skills.

Unfortunately, research on students' meta-skills remains limited in Indonesia, particularly at the University of Bengkulu. Preliminary findings from a study conducted on biology education students enrolled in a plant physiology course revealed that their meta-skills were still low. This was evidenced by frequent late submission of assignments and a lack of focus on task completion, indicating poor self-management. Students were also not accustomed to collaborating; they preferred working individually, and when assigned group projects, only a few members actively participated in completing the tasks, indicating low social intelligence. Moreover, students struggled to connect observed plant physiology phenomena with the underlying concepts. They encountered difficulties in designing and executing proper observation procedures, presenting their findings informatively through tables or graphs, and conducting comprehensive analyses of their experimental results, which indicated low critical thinking, problem-solving, and innovation skills. These findings highlight the need to improve the quality of teaching to develop students' meta-skills.

The development of students' meta-skills can be facilitated through well-designed instructional processes by lecturers. In this regard, a research-based project learning model provides a learning environment conducive to the development of students' meta-skills. Research-based project (RBP) is an innovative pedagogical approach that integrates project-based learning (PjBL) and research-based learning (RBL). Project-based learning (PjBL) is a model that engages students in knowledge construction through the completion of meaningful projects and the development of real-world products (Guo et al., 2020), while research-based learning is a model that incorporates research activities into the learning process to build students' knowledge (Usmeldi et al., 2017). Based on these descriptions, the research-based project in this study refers to a learning model that integrates research as a student project within the plant physiology course.

Several studies have reported that project-based learning (PjBL) is beneficial for enhancing critical thinking and problem-solving skills (Guo et al., 2020; Matahari et al., 2023), creative and innovative thinking skills (Erisa et al., 2021; Yanti & Novaliyosi, 2023), and collaboration and communication skills (Handrianto & Rahman, 2019; Tekad & Pebriana, 2022). Furthermore,

previous studies have also indicated that research-based learning (RBL) improves analytical thinking skills (Suyatman et al., 2021), critical thinking (Daryanes & Sayuti, 2023), problem-solving (Suntusia et al., 2019), and interpersonal skills (Arifin et al., 2022). Based on these findings, the implementation of both project- and research-based learning has the potential to develop self-management, social intelligence, and innovation skills, leading to improvements in students' meta-skills. However, most studies of PjBL and RBL have been conducted independently. Therefore, it is hypothesized that integrating project-based learning and research-based learning will provide students with a more comprehensive learning experience, particularly in developing their meta-skills. Based on this rationale, this study aims to investigate the effectiveness of the research-based project (RBP) model in improving students' meta-skills in a plant physiology course. This research is essential to provide valuable information to educational practitioners regarding the implementation of the research-based project (RBP) model as a means of developing students' meta-skills, which are crucial for supporting their success in a dynamic and ever-evolving world.

METHOD

The research is a quasi-experiment utilizing a nonequivalent pre-test post-test control group design. In this design, the experimental group received an intervention in the form of a Research-Based Project (RBP) model implementation during lectures, whereas the control group underwent treatment using the Scientific Learning Model (5M). The pre-and post-test meta-skills of both groups were subsequently compared. The research design is presented in Table 1 (Subali, 2019).

Table 1. Research Design

Class	Pre-Test	Treatment	Post-Test
Experimental	X ₁	Research-based project (RBP)	Y ₁
Control	X ₂	Scientific learning model (5M)	Y ₂

Description:

X₁: pre-test for the experimental group

Y₁: post-test for the experimental group

X₂: pre-test for the control group

Y₂: post-test for the control group

The research procedure consists of three main steps: 1) Administering a pre-test to evaluate the initial meta-skills of students in both the control and experimental groups before treatment implementation. 2) Executing the treatment, wherein the scientific learning model (observing, questioning, data collecting, reasoning, and communicating) is applied in the control group (Suyanto, 2018), and the RBP model is implemented in the experimental group following these steps: a) start with the essential question: identifying issues, formulating the problem, and formulating research hypotheses; b) design a plan and create a schedule: drafting the research design/proposal; c) monitoring and progress project: collecting data; d) assess the outcome: analyzing data and presenting the results; e) evaluate the experience: reflecting on the learning experiences using the RBP model (Hamidah et al., 2020; Suyatman et al., 2021). 3) Administering a post-test in both the control and experimental groups to assess students' meta-skills after treatment implementation.

The study population comprised students enrolled in the biology education program at the University of Bengkulu in the 2023/2024 academic year. The research sample was selected using purposive sampling. This resulted in a sample consisting of biology education students enrolled in the plant physiology course, which was divided into two classes: one designated as the control group and the other as the experimental group.

Meta-skills were measured using a non-test instrument in the form of a questionnaire consisting of 79 statement items. The questionnaire was designed to assess the domains of meta-skills, which include: 1) Self-management: focusing, adapting, integrity, and initiative; 2) Social intelligence: communicating, feeling, collaborating, and leading; and 3) Innovation: curiosity, creativity, sense-making, and critical thinking (Skills Development Scotland, 2018, 2021; Spencer & Lucas, 2021). The self-management domain consists of 25 statement items, while the social intelligence domain consists of 27 statement items, and the innovation domain consists of 27 statement items. The meta-skills instrument was adapted from the research of Mardiyanti and Siburian (2023), which was validated based on Pearson correlation ($p < 0.05$) and deemed reliable based on Cronbach's Alpha α ($0.99 > 0.60$).

The meta-skill data were analyzed using a One-Way Analysis of Covariance (ANCOVA) test with SPSS version 27. The assumptions that must be satisfied in the One-Way ANCOVA test include the following: 1) the dependent variable must be on a scale or ratio data; 2) the independent variable must be categorical data that divides the data into at least two unrelated groups; 3) independence of observations; 4) absence of significant outliers; 5) residuals data must be normally distributed; 6) the variance of one group must be homogeneous with that of other groups; 7) the covariate must be linearly related to the dependent variable; and 8) there must be homogeneity of regression slopes. Furthermore, the improvement in students' meta-skills was analyzed based on the effect size of the F-test (Partial Eta Squared = η_p^2). The effect size was then interpreted according to the criteria in Table 2 to assess the level of improvement in students' meta-skills (Ellis, 2012).

Table 2. Category of Effect Size for F Test

Eta Squared	Effect Size
0.01	Low
0.06	Medium
0.14	High

RESULT AND DISCUSSION

Result

This study examines the impact of implementing research-based projects (RBP) in plant physiology courses on the meta-skills of prospective biology teacher students. The descriptive statistics of students' meta-skills scores in the control and experimental groups are presented in Figure 1.

Based on Figure 1, the research subjects consist of 32 students in both the control and experimental groups. The average pre-test score in the control group was 40.08, while the average pre-test score in the experimental group was 41.00. The average post-test score in the control class was 78.28, whereas the average post-test score in the experimental class was 86.23.

Before conducting hypothesis testing, the assumptions of the One-Way ANCOVA test were evaluated. The dependent variable in this study comprised interval data (meta-skills scores), while the independent variable consisted of nominal/categorical data (control and experimental classes). Furthermore, the study was conducted under the assumption of independence of observations, and no extreme outliers in meta-skills scores were identified among the participants (with no scores deviating significantly from their respective groups). Consequently, the first, second, third, and fourth assumptions were satisfied. The fifth assumption, pertaining to the normality of residuals for the dependent variable, is presented in Table 3.

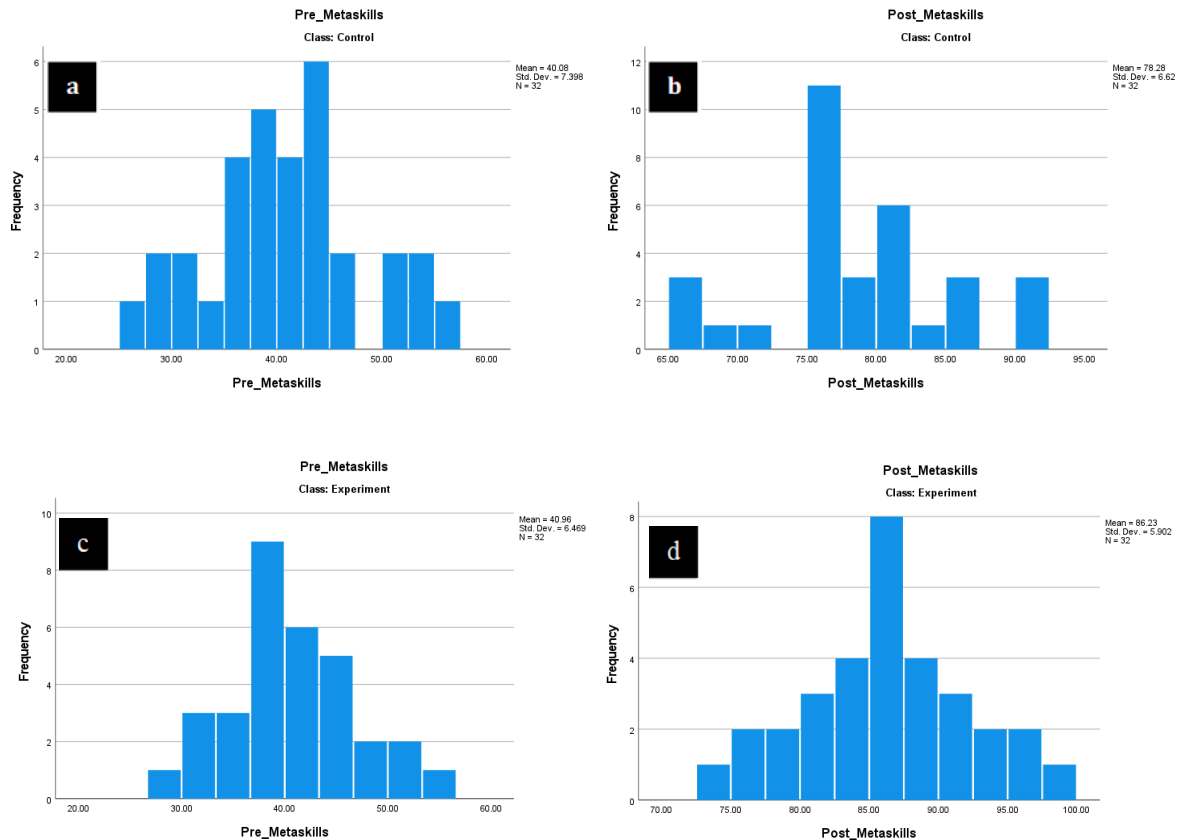


Figure 1. The distribution of meta-skills scores: a) meta-skills scores before intervention in the control group; b) meta-skills scores after intervention in the control group; c) meta-skills scores before intervention in the experimental group; and d) meta-skills scores after intervention in the experimental group.

Table 3. The Normality Test of Residual Data

Description	Shapiro-Wilk			Explanation
	Statistic	df	Sig	
Residual of Meta-Skills Scores	0.965	64	0.069	Normally

The results of the Shapiro-Wilk test in Table 3 indicate that the residuals of the meta-skills scores are normally distributed [$W(64) = 0.965$, $p = 0.069$], thus satisfying the fifth assumption of the One-Way ANCOVA test. The next assumption to be met is data homogeneity, presented in Table 4.

Table 4. The Homogeneity Test of Meta-skills Scores

Description	Levene's Test				Explanation
	F	df1	df2	Sig	
Meta-skills Scores	0.173	1	62	0.679	Homogenous

The results of Levene's test in Table 4 indicate that the variance of the meta-skills data between the classes is homogeneous ($F(1, 62) = 0.173$, $p = 0.679$), thus fulfilling the sixth assumption of the One-Way ANCOVA test. The next assumption to be addressed is the linearity between the covariate and the dependent variable, presented in Figure 2.

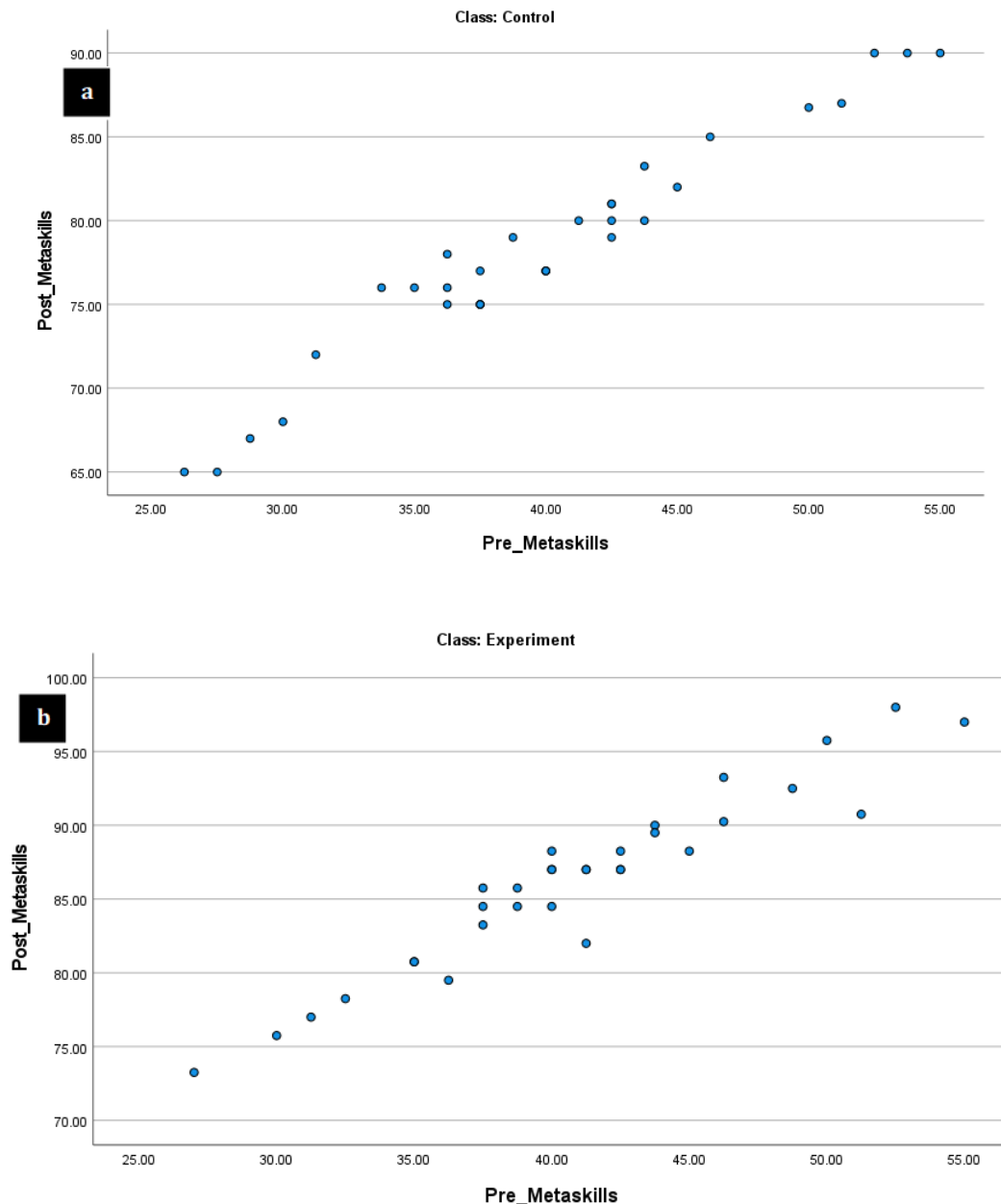


Figure 2. The linearity between the covariate and the dependent variable in a) the control group and b) the experimental group

The scatter plot in Figure 2 indicates that the pre-test scores (covariate) are linearly related to the post-test meta-skills scores (dependent variable), thus fulfilling the seventh assumption of the One-Way ANCOVA test. The next assumption to be addressed is the homogeneity of regression slopes between the two classes, presented in Table 5.

Table 5. The Homogeneity Test of Regression Slope

Description	Test of Between-Subject Effect					Explanation
	Type III Sum of Squares	df	Mean Square	F	Sig.	
Class*Pre-test Meta skills	0.002	1	0.002	0.001	0.979	Homogenous
Error	159,356	60	2.656			

The results in Table 5 indicate that the regression slopes between the pre-test and post-test data for meta-skills across the different classes are homogeneous [$F(1, 60) = 0.001$, $p = 0.979$], thus fulfilling the eighth assumption of the One-Way ANCOVA test. Since all assumptions have been met, the meta-skills data can be analyzed using a One-Way ANCOVA test.

Table 6. The Result of One-Way ANCOVA Test

Description	Test of Between-Subject Effect					Partial Eta Squared	Explanation
	Type III Sum of Squares	df	Mean Square	F	Sig.		
Class	820.292	1	820.292	313.996	<0.001	0.84	High Influence
Error	159.385	61	2.612				

The results in Table 6 show a significant difference in meta-skills between the control and experimental groups, controlling for students' initial meta-skills [$F(1, 61) = 313.996$, $p < 0.001$, $\eta_p^2 = 0.84$]. These findings also indicate that implementing the research-based learning (RBP) model is highly effective in improving students' meta-skills, as evidenced by the effect size value obtained ($\eta_p^2 = 0.84$).

Discussion

One of the essential competencies that university graduates must possess is meta-skills. These skills enable students to be adaptive and responsive in facing the challenges of the 21st century, characterized by uncertainty and heavily influenced by science and technology. In this context, the present study examines the impact of the research-based project (RBP) learning model on students' meta-skills in a plant physiology course.

A research-based Project (RBP) is an innovative pedagogical approach that integrates research-based learning (RBL) into project-based learning (PjBL). Research-based learning is a model that incorporates research activities within the learning process to build students' knowledge (Usmaldi et al., 2017), while project-based learning (PjBL) is a model that engages students in the construction of knowledge through the completion of meaningful projects and the development of real-world products (Guo et al., 2020). In this study, students collaborate in groups to investigate issues related to plant physiology as a research theme within the PjBL framework.

The statistical analysis in Table 6 indicates that the implementation of the research-based project (RBP) model has a high impact on improving students' meta-skills. This finding is consistent with several previous reports that investigated similar learning designs. Previous research has shown that research-based learning can improve students' cognitive and interpersonal skills. Cognitive skills include the ability to analyze situations, apply knowledge, and solve problems, whereas interpersonal skills include teamwork, responsibility, communication, and the ability to plan for independent learning (Arifin et al., 2022). On the other hand, Zakiah and Fajriadi (2020) reported that project-based learning can enhance self-management skills in independent learning. Furthermore, other studies also demonstrated that project-based learning can improve problem-solving abilities and critical thinking (Jeniver et al., 2023), creative thinking (Deria et al., 2023; Fadhillah et al., 2023), and metacognitive skills (Lukitasari et al., 2021). Additionally, project-based learning in teams can enhance collaboration, leadership, and communication skills (Hasanah et al., 2023; Undari et al., 2023). The improvement in the achievement of these skills represents the sub-level competencies of the meta-skills domain.

Meta-skills are high-level skills that stimulate adaptability and drive individual success in any context. Mastery of meta-skills enables individuals to perform well in an ever-changing work environment (Mandro, 2022; Senova, 2020). Meta-skills competencies include self-management

(manage the now), social intelligence (connect with the world), and innovation (create our own change), all of which are interrelated and support the development of other skills. For instance, individuals need the ability to focus on a particular problem, facilitating creativity and innovation as solutions. They then require initiative to implement these ideas ([Skills Development Scotland, 2018, 2021](#); [Spencer & Lucas, 2021](#)). The comparison of students' meta-skills competency achievements between the control and the experimental class is presented in Figure 3.

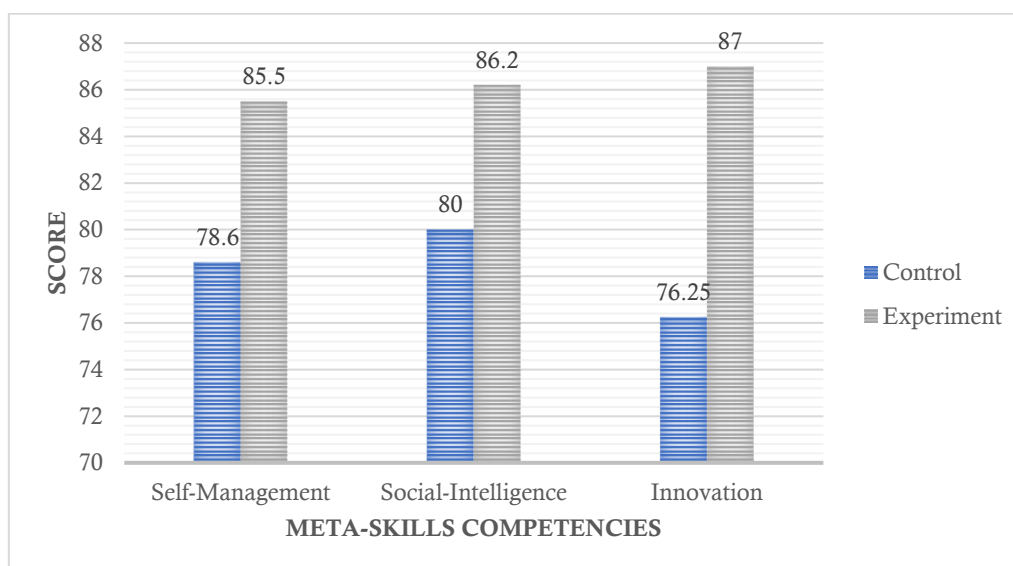


Figure 3. The achievement of meta-skills competencies in the control and experimental classes

The graph in Figure 3 shows that there are differences in the achievement of each undergraduate student's meta-skills competency between the control class and the experimental class. In the control class, the self-management competency achievement was 78.6, social intelligence was 80.0, and innovation was 76.5. Meanwhile, in the experimental class, the self-management competency achievement was 85.5, social intelligence was 86.2, and innovation was 87.0. Therefore, it is evident that the achievement of each meta-skills competency in the experimental class is higher than in the control class. Based on this description, it can be concluded that implementing the research-based project (RBP) model significantly enhances various student meta-skill competencies compared to the scientific learning model in the plant physiology course.

The first competency of meta-skills is self-management. This competency involves self-regulation, which includes self-awareness, goal setting, planning, and behavioral control to achieve the desired outcomes ([Spencer & Lucas, 2021](#)). Self-management encompasses focusing, integrity, adapting, and initiative. Focusing refers to the ability to filter and manage information to concentrate on specific objectives in an era characterized by information overload and constant change. Integrity involves acting according to ethical principles and fairness. Adapting refers to the willingness and ability to continuously develop knowledge, understanding, and skills to remain resilient and flexible in the face of change. The initiative is the readiness to take action and seize opportunities based on self-confidence ([Skills Development Scotland, 2018, 2021](#)). The implementation of the research-based project model helps cultivate these skills. By identifying problems and formulating research hypotheses, students are indirectly required to focus on filtering relevant information while discarding irrelevant data. Adaptive skills and integrity are also developed during this process. To design research in project-based learning, students must expand their knowledge, understanding, and skills related to the research topic to ensure that the research

conducted follows scientific procedures and produces accountable results. Moreover, students need the initiative to realize research by designing and executing the project.

The second competency of meta-skills is social intelligence. This competency pertains to how individuals effectively interact and collaborate with others in complex environments (Spencer & Lucas, 2021). Social intelligence includes the skills of communicating, feeling, collaborating, and leading. Communicating refers to the ability to convey and receive information effectively. Feeling is the capacity to understand and manage one's own emotions while responding appropriately to the emotions of others. Collaborating involves working together with others to convey information or solve problems, while leading is the ability to guide, motivate, and inspire individuals or groups toward a common goal (Skills Development Scotland, 2018, 2021). These skills are developed through the implementation of research-based projects in the learning process. Students actively collaborate in conducting research planned within the framework of project-based learning. In this process, they identify problems, formulate hypotheses, collect and synthesize research data, reframe ideas, and consider the perspectives of other team members in solving the research project. This nurtures students' feeling abilities. On the other hand, the activities of exchanging data/information, debating it, receiving feedback, and answering questions among group members also enhance students' communication and leadership skills.

The third competency of meta-skills is innovation. This competency pertains to the ability to initiate change rather than respond passively (Spencer & Lucas, 2021). The sub-levels of innovation include curiosity, creativity, sense-making, and critical thinking. Curiosity refers to the desire to seek, learn, and explore new information and ideas. Creativity involves the skill of generating new ways to solve problems, answer questions, or express meaning. Sense-making pertains to the ability to comprehend complex information for problem-solving, whereas critical thinking involves the capacity to analyze and evaluate information to make informed decisions (Skills Development Scotland, 2018, 2021). These skills were developed through the implementation of research-based projects in the learning process. During the execution of the research, students engaged in observations to analyze issues related to plant physiology, such as growing media, nutrient fulfillment, plant stress, and other factors affecting agricultural outcomes. The results of these observations become themes for research-based projects, wherein students collaboratively seek information sources to address identified problems and challenges. The proposed solutions were tested experimentally, and the results were analyzed and evaluated for accurate and informative communication. Throughout this process, students demonstrated a high level of curiosity, sense-making, creativity, and critical thinking.

Based on the description above, the research-based project learning model is highly relevant to the needs of biology teacher candidates in developing essential meta-skills. This instructional design provides meaningful learning experiences for students and fosters important skills such as analytical thinking, critical thinking, creative thinking, problem-solving, collaboration, communication, empathy, leadership, responsibility, and self-management, which are all components of meta-skills.

CONCLUSION

This study examines the effectiveness of implementing a research-based project (RBP) learning model in enhancing students' meta-skills during Plant Physiology. Conclusive evidence shows that the application of the research-based project (RBP) model is highly effective in improving students' meta-skills in the Plant Physiology course, based on the results of the One-Way ANCOVA statistical test [$F(1, 61) = 313.996, p < 0.001, \eta p^2 = 0.84$]. The implementation of the research-based project in the learning process not only focuses on mastery of plant physiology

content but also significantly enhances various aspects of students' meta-skills. By integrating systematic RBP syntax, students are trained to become more independent, creative, and collaborative individuals, which are critical criteria for facing challenges in both academic and professional settings. Further research is needed to evaluate the implementation of the research-based project model on other skills and uncover additional positive outcomes associated with this model.

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