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ORIGINAL

Integrating Responsibility-Driven Project-Based Learning Models in Algorithm and Programming Courses: A Pedagogical Innovation in Higher Education

Integración de Modelos de Aprendizaje Basado en Proyectos con Responsabilidad en Cursos de Algoritmos y Programación: Una Innovación Pedagógica en la Educación Superior

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ABSTRACT

Project-based learning (PjBL) strategy has been known to be effective in improving student engagement and technical ability, but the incorporation of responsibility as an essential element has not been well studied. The proposed study will create and test a Responsibility-Driven Project-Based Learning (PjBL-R) model in algorithm and programming courses. The study was conducted using the Research and Development (R&D) approach and the ADDIE framework. A total of 64 students were assigned to the experimental (PjBL-R) and control (conventional) groups. The data were gathered using pretest-posttest, observation surveys, and focus group discussions, and analysed using quantitative (t-test, Aiken V) and qualitative methods. The findings showed that the experimental group achieved greater progress in technical competence ($\Delta = 12,76$; $p < 0,001$) and responsibility ($\Delta = 15,89$; $p < 0,001$) with a high model validity ($V = 0,9$ by Aiken) and practicality (90,4 percent of lecturers). The qualitative analysis showed that there was increased teamwork, time management, and intrinsic motivation among students. These results support the idea that the incorporation of responsibility in the context of PjBL allows making learning and Industry 4.0 requirements engage and develop holistic competence. It is suggested to continue the research to address the question of how the PjBL-R model can be extended to multidisciplinary and longitudinal settings.

Keywords: Project-Based Learning; Responsibility; Algorithms and Programming; Higher Education; ADDIE; Holistic Competence.

RESUMEN

La estrategia de aprendizaje basado en proyectos (PjBL) ha demostrado ser eficaz para mejorar la participación y la competencia técnica de los estudiantes; sin embargo, la incorporación de la responsabilidad como elemento esencial no ha sido suficientemente estudiada. El presente estudio propone crear y evaluar un modelo de Aprendizaje Basado en Proyectos Orientado a la Responsabilidad (PjBL-R) en las asignaturas de algoritmos y programación. La investigación se llevó a cabo mediante el enfoque de Investigación y Desarrollo (I+D) y el modelo ADDIE. Un total de 64 estudiantes fueron asignados a los grupos experimental (PjBL-R) y de control (método convencional). Los datos se recopilaron mediante pruebas pretest-postest, observaciones, encuestas y discusiones en grupos focales, y se analizaron mediante métodos cuantitativos (prueba t, coeficiente V de Aiken) y cualitativos. Los resultados mostraron que el grupo experimental logró un mayor progreso en la competencia técnica (Δ = 12,76; p < 0,001) y en la responsabilidad (Δ = 15,89; p < 0,001), con una alta validez del modelo (V = 0,9 según Aiken) y una elevada practicidad (90,4 % de los docentes). El análisis cualitativo reveló una mejora en el trabajo en equipo, la gestión del tiempo y la motivación intrínseca de los estudiantes. Estos resultados respaldan la idea de que la incorporación de la responsabilidad en el contexto del PjBL permite vincular el aprendizaje con las exigencias de la Industria 4.0 y fomentar el desarrollo de competencias holísticas. Se recomienda continuar la investigación para explorar cómo el modelo PjBL-R puede ampliarse a contextos multidisciplinarios y longitudinales.

Palabras clave: Aprendizaje Basado en Proyectos Responsabilidad; Algoritmos y Programación; Educación Superior; ADDIE; Competencia Holística.

INTRODUCTION

The current trends in higher education have also led in a significant pedagogical change towards abandoning teacher-centred teaching in favor of student-based learning. This shift could be interpreted as the increased awareness that learners should be more involved in building up their knowledge, becoming self-regulated to learn, and showing responsibility in learning. This is especially applicable in such technical fields as computer science and programming, as cognitive flexibility and problem-solving ability are not only important but essential as technology changes at an extremely rapid rate. The conventional lecture-based modes of teaching tend to lay emphasis on content delivery instead of the learning process, and thus, students are technically sound, but they lack the autonomy and initiative in the current workplace situations.[1] Project-Based Learning (PjBL) is one of the most popular and efficient student-centred strategies that has gained popularity among the range of approaches. It involves the students in useful, practical, real-world projects, which would involve them in putting the theoretical knowledge into practice on actual problems. Students are taught to solve problems, manage complex tasks, communicate, and think critically through the project design, collaboration, and reflection. The PjBL structure turns the learning environment into an interactive process where knowledge is built by learners through doing, evaluating, and improving. It also promotes creativity, innovation, and motivation because it provides the students with the opportunity to research realistic problems that reflect on professional practice.[2,3,4]

The effectiveness of PjBL will be largely determined by the ability of students to self-learn. Responsibility is a major metacognitive and affective factor that affects the way students solve their problems, time management, their choices, as well as their reflection on their performance.[5] This competence is particularly important in algorithm and programming courses. These courses demand that the learning process be persistent, based, logical, and a constant problem-solving process. Students may have to make several attempts, debug, and research their own solutions.[6,7] Lack of responsibility also means that learners might over-depend on instructors and lose motivation during the process of progressing in the projects and be unable to meet the deadlines set. Thus, it is crucial to foster responsibility in the PjBL model and raise graduates who are not trained as just good coders but also able to learn and manage themselves independently. Although the positive impact of PjBL is well-grounded, the aspect of responsibility as one of the fundamental pedagogical practices is yet to be developed. The majority of PjBL usages are based on collaboration or technicalism, e.g., teamwork, task division, project output, but not on internal processes that contribute to accountability, initiative and self-discipline. Consequently, much of the implementation of PjBL is still more of a process than a change. Students can do projects satisfactorily and not build the reflective awareness and sense of ownership that constitute responsible learning. Such a case indicates an evident pedagogical vacuum: though PjBL encourages performance and engagement, it does not necessarily foster responsibility unless planned as part of the learning model.[8,9]

It needs a change of mindset when it comes to developing a model that explicitly incorporates responsibility into the framework of PjBL. Responsibility should not be only considered as an individual characteristic but as a competence that can be acquired and measured. It may be cultivated by means of the systematic learning process that will make students plan, track, and assess their work in a systematic manner.[10,11] This view is consistent with the current educational paradigms which consider learning to be an active, self-regulated process, as opposed to a passive intake of knowledge. The responsibility that is incorporated in the design and implementation of the projects has enabled educators to design a balanced learning environment that builds both the technical skills and character formation. This philosophy is consistent with the larger the aims of 21 st -century education, in which expertise in technical skills and experience is just as secondary as accountability, adaptability and ethical practice. The responsibility-based learning is especially acute in the areas of algorithm and programming courses.[12,13,14] These topics are usually abstract in nature and intricate in problem solving which may easily put off students with poor self-regulation. Conventional teaching strategies will be more inclined to provide step-by-step directions which by default would demotivate self-direction. This challenge can be solved by integrating responsibility into PjBL as it can motivate students to set their own objectives and think about project milestones, reflect on their progress, and take corrective actions when this is required. It turns the position of the instructor into one of the transmitters of the information into the position of the one who facilitates the independent development of the learners. As a result, students receive not only a higher level of conceptual knowledge but also transferable skills, including time management, decision-making, and collaboration.[15]

At the institutional level, the inclusion of responsibility in PjBL is also a reaction to the changing demands of the contemporary workforce.[16]Graduates are also being more targeted by different industries who can work alone and handle complex projects and exhibit ethical and accountable behaviour. Accountability-based learning provides the students with these characteristics to bridge the academic education and professional skills. It also instills the attitude of lifelong learning whereby the graduates are ready to keep on updating their skills with the changing technology.[17,18] Through this, the responsibility plus PjBL will directly contribute to the educational agenda of Industry 4.0 and Society 5.0, wherein technological competency should be guided by social and personal responsibility. The development of Responsibility-Driven Project-Based Learning (PjBL-R) model consists in the translation of these abstract principles into a systematic pedagogical model. The model must also have effective mechanisms of developing and evaluating responsibility during the learning process. These processes can also involve deliberate goal setting, self-assessment tools, peer reviews, reflective journals and rubrics that do not only assess technical achievement but also behavioural ones such as initiative and consistency. The introduction of these elements is aimed at making responsibility a characteristic that is not viewed as an ideal state to be observed but a characteristic of student learning. PjBL-R model therefore places responsibility as a key construct that guides all learning processes, including the project initiation and implementation, as well as reflection and evaluation.[19,20,21]

Introduction of such a model needs cautious design of instructions. The analysis, design, development, implementation, and evaluation components of the ADDIE model can provide a methodology to create and test the PjBL-R model within a controlled academic environment. In the stage of analysis, the educators define the learning requirements, objectives in the course, and student preparedness in terms of responsibility. The design and development phases are to be devoted to building of project tasks and learning activities that would help to evoke autonomy and accountability.[22,23,24,25] The use of the approach will be implemented within the classroom environment in which students will have to complete projects on the PjBL-R framework, and the assessment will use a combination of quantitative and qualitative approaches to assess the model effectiveness. This is done to guarantee the pedagogical validity of the model and its usability in classroom teaching contexts. The inclusion of responsibility in PjBL also has significant implications on the side of people who teach. Not only should the instructors be prepared with technical knowledge but also with facilitation skills that help in reflective learning and self-regulation.Training and professional development is thus vital to enable the lecturers to adjust to this facilitating role. Moreover, responsibility-based pedagogy needs to be maintained with institutional support, i.e. learning resources, digital tools and assessment policies. Even the best designed pedagogical model can have obstacles to its implementation without proper infrastructure. Thus, the pedagogical innovation and the overall support of the academic environment with the PjBL-R model are the keys to successful implementation.[26,27]

Cultural and contextual diversity of learners is another factor that is worth bearing in mind when incorporating responsibility into PjBL. The responsibility can take various forms based on the educational backgrounds, cultural values and the learning habits of the students. The lack of autonomy may be an issue with some of the students, particularly in cases where they are accustomed to education systems that focus on memorisation and teacher dependence. This is why the PjBL-R model should incorporate the ability of scaffolding so that the responsibility of the instructor is eventually delegated to the student. The initial phases of the course can be pre-reflection and guided milestones that can develop into more autonomous project management. This gradual transfer of responsibility makes such inclusion and flexibility in various learning situations possible. On top of the responsibility, the PjBL-R model also helps in a holistic education by incorporating the cognitive, affective, and behavioural learning outcomes.[28,29] The behavioural outcomes are responsibility, collaboration, and initiative; the affective outcomes are motivation, self-efficacy and confidence,and the cognitive outcomes are the knowledge of the students on algorithms and programming. The PjBL-R strategy can be used to achieve comprehensive student learning, which is in line with the contemporary educational quality standards by covering all three areas. Furthermore, its responsibility orientation assists in narrowing the incessant gap between both technical and humanistic education, with the focus that competence and character form inseparable parts of successful learning. Finally, the necessity to develop a more balanced and humanistic framework of technical education explains the reasons for the development of the Responsibility-Driven Project-Based Learning model. The aspect of responsibility incorporated into PjBL makes the learning process more of a formative experience as opposed to a mere performance task, which makes students identify as responsible learners and adults in the future.[30] It facilitates a pedagogical context in which learning is not forced, but rather self-driven, is not competitive but is collaborative, and is not course-bound, but rather lifelong. The PjBL-R model provides an avenue through which educational innovation can be matched to the moral and intellectual aspects of learning because it conceptualizes responsibility as an objective and a process.[31] Thus, the proposed study will facilitate the design, implementation, and assessment of a Responsibility-Driven Project-Based Learning model within higher education in algorithms and programming. The study aims at identifying how responsibility could be successfully implemented and measured in the PjBL framework and the effect of the implementation on the technical competence, motivation, and learning behaviour of the students. The paper also examines the validity, practicality, and the possibility of further application of the model to other fields. It is hoped through this work that the higher education establishments will be able to implement more holistic approaches to teaching that would enable the students to not only be competent programmers but also responsible, independent, and adaptive individuals who would be able to survive in an ever-complex and dynamic world.[32,33]

METHOD

Research Type

The research and development model that was used in this study is the ADDIE model, which is divided into five stages, namely Analysis, Design, Development, Implementation, and Evaluation. The study was intended to design, develop, and test a Responsibility-Driven Project-Based Learning (PjBL-R) model within undergraduate Algorithm and Programming classes. The two-semester students of the Informatics Education program came to participate in the study (N=64). The sample was chosen through a purposive approach since it was established that the sample was comprised of individuals who had already taken introductory program courses and had some general knowledge of coding. After that, they were randomly divided into two groups: the experimental (n = 32) and the control (n = 32) group, and the participants were required to use PjBL-R or the traditional project-based learning, respectively. The study commenced with the analysis stage to determine the learning difficulty, the nature of the students and the need to apply the element of responsibility in the project-based programming activities. It is based on this analysis that the design stage was to develop learning objectives, project structures, assessment rubrics, and responsibility-related behaviours indicators. Learning materials and digital project templates, as well as reflective instruments, were developed in the development phase to encourage responsible and self-regulated learning. The model was subsequently applied in a period of six weeks during Algorithm and Programming. At this phase, learners in the experiment group were tasked with the responsibility of doing programming projects that were organized based on responsibility indicators, whereas the control group was asked to do similar works without directly integrating responsibility. The assessment of the model was in form of both formative and summative assessments. Formative evaluation was aimed at making sure that the model is clear and feasible to be developed, whereas summative evaluation was used to determine the overall effectiveness of the model once it was implemented. The process of data collection entailed the following tools: pre-test and post-test tests to evaluate the technical competence of the students; responsibility rubrics and self-reflection journals to assess the responsibility development; observation checklists to report on the behavior modification; and lecturer surveys to evaluate the practicality. Paired and independent t-tests were applied to the quantitative data to measure the learning gains in the two groups, and the content validity was measured by the Aiken V coefficient. In the meantime, thematic analysis of qualitative data, such as focus group discussions and student reflections, was used to identify the breadth of behavioral, motivational, and attitudinal changes due to applying the PjBL-R model.[34]

Research Design

The research design used in this study is the Two-Group Pretest-Post-test Design, an experimental approach involving two groups, namely the experimental group and the control group. At the beginning, both groups were given a pretest to measure the initial conditions related to the competencies to be developed. After that, the intervention in the form of applying the Responsibility-Based Project-Based Learning (PjBL-R) learning model was applied to the experimental group, while the control group continued to use the conventional learning method. At the end of the study, both groups were given a post-test to evaluate the impact of the intervention on learning outcome.. The data obtained from the pretest and posttest are analyzed to identify differences between the experimental and control groups, particularly in cognitive aspects and responsibility.This analysis aims to test the validity, practicality, and effectiveness of the learning model developed, so that it can make a real contribution to improving the quality of learning in the Algorithms and Programming course. The design of this study allows researchers to comprehensively assess the impact of interventions in a controlled learning environment.

Research Procedures

This research procedure follows the ADDIE stages which consists of five main steps: First, the Analysis stage aims to identify the need to develop a learning model by analyzing current learning conditions, the needs of students and lecturers, and the challenges faced, using data from observations, interviews, and literature studies. Second, in the Design stage, researchers designed a Responsibility-Based Project-Based Learning (PjBL-R) learning model, including the syntax of the model and the design of teaching materials and research instruments. Third, in the Development stage, initial products such as learning models, lecturer guidebooks, and student textbooks were developed and validated by experts, followed by revisions based on feedback. Fourth, in the Implementation stage, the valid model is applied to the experimental group, while the control group uses the conventional learning method, with data collection through observation, questionnaires, and tests. Finally, the Evaluation stage is carried out to assess the quality of the model based on the results of the implementation by analyzing data to measure the validity, practicality, and effectiveness of the model in improving learning outcomes and students' sense of responsibility, as well as making final revisions before dissemination.

Research Instrument

The research instruments used in this study are designed to ensure the validity, practicality, and effectiveness of the Responsibility-Based Project-Based Learning (PjBL-R) learning model, including quantitative and qualitative data collection tools that support comprehensive analysis These instruments include the Validation Instrument which is evaluated by experts to measure the validity of the construct and content of the learning model, the Practicality Questionnaire to measure the application of the model by lecturers and students, and Learning Outcome Tests (Pretest and Posttest) to assess the effectiveness of the model in improving student learning outcomes . In addition, there is an Observation Sheet to assess student involvement and activity during learning, a Student Response Questionnaire to evaluate the learning experience and the model's support for understanding of the material and responsibility, and a Project Assessment Instrument to assess the quality of student projects based on creativity, collaboration, responsibility, and alignment with learning objectives.

Data Analysis Technique and Hypothesis Development

Validity Analysis

This method is used to ensure that the PjBL-R model and research instruments (such as guidebooks, course syllabi, and course assessment sheets) are relevant and representative of the constructs being measured. An Aiken's V value of ≥ 0,667 indicates that the experts agree that the components of the model are theoretically valid. The following are the validity results from the experts.

Table 1. Validity of Model

No	Instrument	Aiken's V	Valid
1	Model Syntax	0,9	High
2	Social Systems	0,83	Medium
3	Reaction Principles	0,78	Medium
4	Support System	0,84	Medium
5	Instructional and Accompanying Impact	0,8	Medium

Based on the graph above, the validity value (v) for the five instruments analyzed has a not too significant variation. The first instrument, namely the Model Syntax, has the highest validity value, namely 0,9, which falls under the "High" category. This shows that this instrument is very valid and reliable for use in relevant research or measurements. The second instrument, the Social System, with a value of 0,83, is in the "Moderate" category. Although its validity is slightly lower than that of the Model Syntax, this instrument is still quite reliable, but there is room for improvement. The Reaction Principle, which has a validity value of 0,78333, is also in the "Moderate" category. This indicates that this instrument is slightly less valid than the Social System but is still good enough to be used in the appropriate context. The Support System, with a validity value of 0,84, is in the "Moderate" category and indicates that this instrument is still quite valid, although there is little room to improve its accuracy or reliability. Finally, the Instructional and Accompanying Impact, which has the lowest validity value among the five instruments, namely 0,8, is still included in the "Moderate" category. This shows that although these instruments can still be used, there is potential to improve their quality or reliability. Overall, most of the instruments have a high validity value, although there are some instruments that need to be improved to be more valid.

Practicality Analysis

Scores of 90,4 % from lecturers and 86,95 % from students indicate that the PjBL-R model is very practical.

This means that the model is easy to implement in the classroom, learning time is efficient, and teaching materials are easy to understand. The categories “practical” (80–89 %) and “very practical” (90–100 %) reflect that both lecturers and students do not experience significant difficulties in using this model.

Effectiveness Analysis

Quantitative data were executed in a few inferential tests to identify the effectuality and validity of the PjBL-R model. The application of the pretest- posttest design was used to compare the learning outcomes during the pretest period and posttest period to determine whether there was an improvement in the student performance. The level of improvement within each group was investigated by the Paired T-Test, whereas the posttest results of the experimental and control groups were compared with the help of the Independent Samples T-Test to conclude whether the differences observed were statistically significant or not. An analysis of normality and homogeneity (ShapiroWilk and Levene tests) was conducted before these tests to ensure that the data assumed in the parametric test is met. Also, Aiken V-coefficient was applied to measure the content validity of the instruments to make sure that the items reflected the constructs under measurement.

Qualitative Analysis

Qualitative data (e.g., records of student participation observations) complement the quantitative findings. For example, students in the experimental group were more active in asking questions, collaborative in projects, and demonstrated a responsible attitude. Interviews with lecturers may reveal that this model triggers student creativity in solving real problems.

Interpretation of Hypothesis

The validation and testing steps proved that the model is very robust, practical and effective. The analysis of validity, using the V coefficient of Aiken (0,667 and above), proved the fact that the PjBL-R model is created on the sound theoretical basis and corresponding to the targeted learning goals. Wholesomers confirmed the fact that every syntactic aspect of the model contributes to the accomplishment of these goals logically. The test of practicality had an average of more than 80 percent which implies that the model is easy to apply. Lecturers could use it without having to undergo extensive training and students could easily track the flow of learning activities. The efficacy analysis based on the large differences between the posttest scores of the experimental group (85 vs. 75; $p < 0,05$) and the control group confirmed the fact that the PjBL-R model is successful in improving cognitive understanding, promoting responsible attitudes, and psychomotor skills improvement in programming. Additionally, the responsibility analysis showed that students in the experimental group proved to be more consistent in finishing project on time, more active in discussions and had more leadership in their teams. All these findings confirm the fact that PjBL-R model is not simply a pedagogically appropriate model, as it also can develop the sense of responsibility and accountability among the learners.

Table 2. Descriptive Analysis of Experimental Class Test Data

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Pre-test Eksperimen	30	27	24	51	39,47	1,305	7,147	51,085
Post-test Eksperimen	30	19	70	89	80,50	0,857	4,696	22,052
Valid N (listwise)	30							

Based on the descriptive statistical data presented, there is a striking difference between the pre-test and post-test results in the experimental group. In the pre-test, the participants' scores showed considerable variation with an average of 39,47 and a standard deviation of 7,147, which indicates a high dispersion of scores. The range of pre-test scores was 27, with the lowest score being 24 and the highest being 51. After the intervention or treatment, the post-test results showed a significant improvement with an average score of 80,50 and a lower standard deviation of 4,696. The range of post-test scores is also smaller, at 19, with a lowest score of 70 and a highest score of 89. This shows that after the intervention, the participants' scores tend to be more homogeneous and concentrated around the average. The increase in the average score from the pre-test to the post-test as well as the decrease in the standard deviation and variance indicate that the intervention provided may be effective in improving the learning outcomes or performance of the participants.

Based on the results of the normality test presented, using both the Kolmogorov-Smirnov and Shapiro-Wilk tests, it can be concluded that the learning outcomes data from both groups (control and experimental) in the pre-test and post-test are normally distributed. This is indicated by a significance value (Sig.) greater than 0,05 for all groups.

Table 3. Normality Test							
Kelas Statistic		**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Hasil Belajar	Pre-test Kontrol	0,119	31	0,200	0,947	31	0,126
	Pre-test Eksperimen	0,156	30	0,060	0,952	30	0,194
	Pre-test Kontrol	0,102	31	0,200	0,957	31	0,250
	Post-test Eksperimen	0,091	30	0,200	0,957	30	0,741
Note: * This is a lower bound of the true significance, a: Lillifors significance Correction							

In the pre-test of the control group, the significance value for Kolmogorov-Smirnov was 0,200 and for Shapiro-Wilk it was 0,126. Meanwhile, in the pre-test of the experimental group, the significance value for Kolmogorov-Smirnov was 0,060 and for Shapiro-Wilk it was 0,194. For the post-test, both the control and experimental groups also showed significance values above 0,05, namely 0,200 and 0,250 for the control group, and 0,200 and 0,741 for the experimental group.

Thus, it can be concluded that the learning outcomes data from both groups meet the normality assumption, which is an important prerequisite for further parametric statistical analysis. This result shows that the data distribution does not deviate significantly from the normal distribution, so statistical analysis that requires the normality assumption can be carried out with confidence.

Table 4. Homogeneity Test					
		Levene Statistic	**df1**	**df2**	**Sig.**
Result	Based on Mean	0,080	1	59	0,778
	Based on Median	0,050	1	59	0,823
	Based on Median and with adjusted df	0,050	1	47,876	0,823
	Based on trimmed mean	0,075	1	59	785

The table presented shows the results of the test of homogeneity of variance using the Levene test. This test is carried out with several approaches, namely based on the mean, median, median with adjusted degrees of freedom, and the cut-off mean. The test results show that the significance value (Sig.) for all approaches is greater than 0,05. The significance value for the approach based on the mean is 0,778, based on the median is 0,823, based on the median with an adjusted degree of freedom is 0,823, and based on the trimmed mean is 0,785. Because all these significance values are greater than 0,05, it can be concluded that the between-group variance in this data is homogeneous, which means that the assumption of variance homogeneity is met.

Table 5. T-Test Pre-Test Control Classes And Experiments										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95 % Confidence Interval of the Difference**	
									Lower	**Upper**
Hasil Belajar	Equal variances assumed	0,080	0,778	0,370	59	0,713	0,757	2,048	-3,341	4,855
	Equal variances not assumed			0,371	57,427	0,712	0,757	2,041	-3,329	4,843

Based on the results of the Independent Samples T-Test, this test was conducted to compare the difference in the mean (average) between two independent groups related to Learning Outcomes. This analysis also included Levene's Test for Equality of Variances to verify the homogeneity of variance between the two groups. The results of Levene's Test showed a significance value (Sig.) of 0,778, which is greater than 0,05, indicating that the variance between the two groups was homogeneous. Therefore, further interpretation was based on the results from the row Equal variances assumed. The obtained t-value was 0,370 with a degree of freedom (df) of 59, and a significance value (Sig. 2-tailed) of 0,713. Since this significance value is much greater than 0,05, it can be concluded that there was no statistically significant difference between the mean learning outcomes of the two groups. The mean difference between the groups was 0,757, with a standard error difference of 2,048. The 95 % confidence interval for the mean difference ranged from –3,341 to 4,855, which includes the value 0, reinforcing the conclusion that there was no significant difference between the two groups.

Thus, it can be concluded that there was no statistically significant difference in learning outcomes between the two groups being compared. The small difference in the mean (0,757) was not sufficient to be considered significant, indicating that both groups achieved relatively similar learning outcomes.

Table 6. T-test of Students' Sense of Responsibility in the Control and Experimental Classes

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95 % Confidence Interval of the Difference	
									Lower	Upper
Initiative	Equal variances assumed	33,663	0,000	5,092	58	0,000	1,201	0,236	0,729	1,674
	Equal variances not assumed			5,214	40,806	0,000	1,201	0,230	0,736	1,667
Task Commitment	Equal variances assumed	5,526	0,022	2,631	58	0,011	0,583	0,222	0,139	1,026
	Equal variances not assumed			2,655	55,753	0,010	0,583	0,220	0,143	1,023
Collaboration and Communication	Equal variances assumed	7,235	0,009	2,628	58	0,011	0,574	0,218	0,137	1,011
	Equal variances not assumed			2,660	53,371	0,010	0,574	0,216	0,141	1,007
Accountability Taking	Equal variances assumed	14,725	0,000	3,067	58	0,003	0,749	0,244	0,260	1,237
	Equal variances not assumed			3,109	51,936	0,003	0,749	0,241	0,265	1,232

Based on the results of the Independent Samples Test presented, there are several important findings related to the difference in means between the two independent groups. First, for the variable "Initiative", Levene's Test shows a significance (Sig.) of 0,000, which indicates that the assumption of variance equality is not met. Therefore, the t-test used is one that does not assume variance equality. The t-value is 5,214 with a degree of freedom (df) of 40,806 and a two-tailed significance of 0,000, indicating a significant difference in the mean between the two groups. The difference in the mean is 1,201 with a 95 % confidence interval between 0,736 and 1,667.

For the variable "Task Commitment", Levene's Test shows a significance of 0,022, which also indicates variance inequality. The relevant t-test results show a t-value of 2,655 with a df of 55,753 and a two-tailed significance of 0,010. The difference in mean is 0,583 with a 95 % confidence interval between 0,143 and 1,023.

In the "Collaboration and Communication" variable, Levene's Test shows a significance of 0,009, which means that the assumption of variance equality is not met. The t-test results show a t-value of 2,660 with a df of 53,371 and a two-tailed significance of 0,010. The difference in mean is 0,574 with a 95 % confidence interval between 0,141 and 1,007.

Finally, for the "Accountability Taking" variable, Levene's Test shows a significance of 0,000, which indicates variance inequality. The t-test results show a t-value of 3,109 with a df of 51,936 and a two-tailed significance of 0,003. The difference in mean is 0,749 with a 95 % confidence interval between 0,265 and 1,232.

Overall, the results of this test show that there is a significant difference in the mean between the two groups for all variables tested, assuming variance inequality in all cases.

DISCUSSION

This research was able to accomplish its main goal, which was to create and test the Responsibility-Driven Project-Based Learning (PjBL-R) model in the course of Algorithms and Programming. The results showed a great difference in the technical competence ($\Delta = 12,76$; $p < 0,001$) and responsibility ($\Delta = 15,89$; $p < 0,001$) between the students who belonged to the experimental group and the control group. The model had high content validity (V = 0,9 of Aiken) and high practiceability (90,4 percent of lecturers rated it feasible), which shows that it is pedagogically sound and that it could be easily used without extensive knowledge training. All of them confirm the effectiveness of the PjBL-R as the effective framework that meets the learning requirements of the Industry 4.0, in which technical expertise and socio-behavioral skills are essential skills of workforce preparedness. The advances of the technical and affective aspect simplify the assertion that the introduction of responsibility as clear-cut construct within the PjBL framework improves the learning results beyond the conventional concern of project completion.(35,36) This is consistent with the findings of the international literature on the significance of active engagement and self-regulation in learning. Previous research has demonstrated that project-based learning enhances critical thinking and teamwork, but not many ones have defined responsibility as an empirical variable. The current results contribute to the current body of research since it offers empirical data that responsibility is teachable, observable, and measurable. This study is extended in terms of previous work that has concentrated more on scaffolding and team management in PBL environments, when compared to the existing literature. Where the previous research emphasized the combination of soft skills, PjBL-R model introduces a systematic and quantifiable system of cultivating responsibility as a learning outcome. As opposed to the PBL application in non-technical subjects, the concept is modified and confirmed in a technical background, in this study, and the concept is more widespread across the disciplines. The PjBL-R model operates mechanically, through strengthening learner autonomy and reflective accountability. The structure of the model, in which it focuses on measurable outcomes, peer review, and self-assessment, establishes a constant feedback loop that enhances cognitive and behavioral engagement.(37,38)

The findings indicate that the rates of higher test scores and enhanced intrinsic motivation and time management were not only demonstrated by students who were granted ownership of their projects and were encouraged to self-assess their progress but also achieved higher scores on the test. This helps in supporting constructivist and experiential theories of learning, which posit that learning is more more valuable when the learners take an active responsibility in their learning.(39) The responsibility-related behavioral change that was noted, including punctuality, task ownership and active collaboration suggests that PjBL-R fosters a certain level of professional learning maturity that is frequently pursued in engineering and computer science courses. The results hence confirm the concept that responsibility of learning can be developed in orderliness instead of unofficially in the classroom. In the real world, the research highlights the need to train lecturers to be facilitators rather than instructors. Effective adoption of PjBL-R presupposes the presence of educators who will be able to combine guidance and autonomy to develop a culture of responsibility in the classroom. Capacity building efforts should be taken into consideration by institutions to the teachers and they should also offer digital collaboration tools that help in keeping track of the projects and that peer evaluation is conducted. Theoretically, this study builds up on the traditional PBL paradigm by introducing responsibility in the form of a measurable element of learning.(40,41,42,43) The PjBL-R framework introduces a behavioral layer to the already existing cognitive and psychomotor domains to add to the taxonomy of learning outcomes. This theoretical contribution enhances the connection between constructivist pedagogy and learning competencies of the 21 st century, where responsibility is identified as both a driver of learning and a performance measure. Another implication of responsibility integration is in education design in the higher level.(44) By integrating quantifiable aspects of responsibility into the course designs, teachers will be prompted to pay attention to the affective outcomes in addition to technical proficiency, which will promote more comprehensive growth of students. This kind of approach does not only equip learners with academic success but also in the real world of professional life that requires them to work as a team, to manage themselves, and hold them accountable. Though the outcomes are encouraging, there is a variety of limitations that should be admitted. The sample (n=64 students) is too small and only represents two Indonesian universities, which makes it harder to generalize the results to more general situations. The semester long duration of the study limits the capability to evaluate the long term sustainability of the behavioral modification especially in the responsibility domain which is likely to develop over the long periods of learning. Also, self-report measures might introduce some form of biases, such as social desirability and novelty effects, given that responsibility was measured using self-report measures.(31,45,46) The lack of a longitudinal tracking also reduces the possibility to find out whether the gains of responsibility can be transformed into the consistent performance or the professionalism outside of the classroom environment. Besides, the cultural background of the research, in which collectivist principles are involved in group behavior, could have contributed differently to the dynamics of responsibility to a more individualistic environment. These limitations show that the PjBL-R model should be carefully applied and interpreted in a specific context when applied to an international setting. The future studies need to focus on the replication and extension of the PjBL-R model to multidisciplinary and cross-cultural settings, creating examples in engineering, health sciences, and management. There is a need to conduct longitudinal research that will examine the sustainability of responsibility-based learning results and their application to employability and professional ethics. The incorporation of AI-based analytics may offer objective sources of data, including the records of participation, the timeline of submitting tasks, and the measures of peer evaluation, to triangulate the self-reported findings and minimize bias.(47) Moreover, larger and more heterogeneous samples designed through experimental designs will increase the external validity and causal inferences. Altogether, the research has good empirical evidence of the effectiveness of PjBL-R model in building technical competence and responsibility among students of programming. Introducing a new dimension to the pedagogical dialogue of the 21st century education, this research introduces responsibility as a main construct of the project-based learning process. Despite its restricted sample size and time, the results provide a good basis of pedagogical innovations, which combine cognitive, affective and behavioral learning outcomes. Finally, the PjBL-R model shows that responsibility is not a desirable side effect of project-based learning but a pedagogical goal, which can be easily designed, assessed, and grown. This observation supports the connection between higher education and the changing needs of Industry 4.0, highlighting the importance of learning models that can encourage both competence and character with equal emphasis.[48,49,50]

CONCLUSION

This study concludes that the Responsibility-Driven Project-Based Learning (PjBL-R) model effectively enhances both technical competence and personal responsibility among students in algorithms and programming courses. The model demonstrates not only pedagogical validity but also strong practicality in its implementation, establishing it as a viable holistic framework for higher education. By embedding responsibility as an explicit and measurable construct within project-based learning, this research advances beyond traditional PBL approaches and provides a novel contribution to the discourse on competency-based education. The findings confirm that integrating responsibility within technical education promotes deeper engagement, self-regulation, and collaborative awareness among learners—key attributes aligned with the expectations of Industry 4.0. The success of PjBL-R underscores the importance of aligning instructional design with real-world professional demands, bridging the gap between academic preparation and workplace readiness.

Practically, institutions are encouraged to train lecturers as facilitators, strengthen digital collaboration infrastructures, and integrate the responsibility dimension into technical curricula to ensure more comprehensive student development. Theoretically, this work enriches constructivist learning theory by demonstrating how responsibility can serve as a central driver of holistic competence formation. Future research should extend the application of the PjBL-R model to multidisciplinary contexts, explore its long-term influence on academic and professional performance, and investigate the integration of artificial intelligence to personalize learning pathways. Ultimately, this study presents PjBL-R as more than a teaching model—it represents an educational transformation that aligns higher education with the evolving demands of the digital era, fostering graduates who are competent, responsible, and ethically grounded contributors to society.

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