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Chemistry Learning Revolution: Problem Based Learning to Improve the Responsible Character Students in Atomic Structure Material

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ABSTRACT

Purpose of the Study: This study aims to analyze the impact of the Problem-Based Learning (PBL) model on the development of students' responsibility character in Chemistry education, with a specific focus on the challenging topic of atomic structure among 11th-grade high school students. Amid increasing concerns about character education in STEM subjects, this study seeks to fill the gap by exploring how active learning models influence affective outcomes alongside cognitive achievement.

Methodology: A mixed-methods explanatory design was employed, incorporating a quasi-experimental approach with pretest-posttest control groups. Quantitative data were collected through self-assessment questionnaires, peer evaluations, and teacher observation sheets, while qualitative insights were gathered via semi-structured interviews and thematic analysis of student reflections. The triangulation of data sources provided a comprehensive view of how PBL implementation affects student responsibility.

Main Findings: The findings revealed that students in the experimental group demonstrated significant improvements in their responsibility character compared to the control group. Higher posttest scores reflected positive behavioral changes in engagement, discipline, and task accountability during Chemistry learning activities. Qualitative data further supported that PBL encouraged students to take ownership of their learning process, collaborate effectively, and complete tasks with greater autonomy and diligence.

Novelty/Originality of this Study: This research offers a novel perspective by applying PBL not only as a cognitive learning strategy but also as a tool for character development in complex Chemistry topics. It advances the understanding of integrative pedagogical models that simultaneously nurture academic proficiency and essential life skills, particularly responsibility, in secondary science education.

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1. INTRODUCTION

Character education in high schools plays a very important role in shaping the younger generation who are not only academically intelligent, but also have good moral values. At the high school level, students are in a transition period from adolescence to adulthood, so character education can help them develop attitudes that are

in accordance with the demands of social and professional life in the future [1]-[3]. One of the characters that is very necessary for students' success in everyday life is the character of responsibility, which teaches them to be responsible for themselves, their tasks, and the decisions they make [4]-[6].

The character of responsibility in learning is an attitude that every student must have so that they can succeed in their studies. Students who have a responsible character tend to be more disciplined, independent, and motivated to complete tasks well [7]-[9]. In the context of learning in schools, responsibility also includes the ability to manage time, complete tasks on time, and maintain the quality of their learning outcomes [10]-[12]. Therefore, it is important to foster an attitude of responsibility in students, so that they not only excel academically, but also have mature behavior and are ready to face the challenges of life [13]-[15].

Chemistry subjects are often a challenge for students at the high school level, especially in complex materials such as Atomic Structure [16]-[18]. Many students find it difficult to understand abstract concepts related to this material, causing them to be less responsible in participating in learning [19]-[21]. Lack of understanding of the material being taught often makes students unmotivated to study seriously [22]-[24]. Therefore, a learning method is needed that is able to overcome this challenge in a more interesting way and actively involve students in the learning process, so that they can improve their understanding and responsibility for learning.

One method that can be a solution to overcome this challenge is to use the Problem Based Learning (PBL) learning model. PBL is an approach that emphasizes the active involvement of students in solving real problems that are relevant to the learning material [25]-[27]. With PBL, students are not only invited to understand the theory, but also to collaborate, think critically, and be responsible for the process and results of their learning [28]-[30]. PBL allows students to connect the knowledge they gain with real-world situations, thereby improving their understanding of the material and fostering a character of responsibility.

Previous research has explored the application of problem-based learning (PBL) models in various educational contexts, including in secondary school chemistry learning. For example, a study examined the effectiveness of PBL on 9th grade students' understanding of intermolecular forces, finding that PBL can improve students' conceptual understanding and address existing misconceptions [31]. In addition, a meta-analysis of student-centered learning methods, including PBL, showed that this approach had small to moderate positive effects on student motivation. This motivation includes students' beliefs, perceptions of task value, and reasons for engaging in the task [32].

However, research that specifically explores the use of PBL to develop students' character of responsibility in chemistry learning, especially in Atomic Structure material at the high school level, is still limited. Most previous studies have focused more on cognitive aspects, such as conceptual understanding and learning motivation, rather than on the development of students' character or attitudes [33]-[35]. Therefore, there is a research gap that needs to be filled regarding how the application of PBL can affect the development of students' character of responsibility in the context of chemistry learning. The current study aims to fill this gap by exploring the impact of PBL on the character of responsibility of grade 11 students in Atomic Structure material, so that it can provide new contributions to the literature on chemistry education at the high school level.

This study brings novelty by focusing on the application of the Problem Based Learning model in the context of Atomic Structure material in Chemistry subjects in grade 11. Although PBL has been widely applied in various disciplines, the use of this model in developing students' character of responsibility in Chemistry material, especially Atomic Structure, is still limited. Therefore, this study seeks to further explore how PBL can be used to improve students' character of responsibility in Chemistry learning, while providing new contributions to the literature of Chemistry education at the high school level.

The urgency of this study lies in the importance of finding a learning method that not only improves students' understanding of the subject matter, but also strengthens their character. Therefore, this study aims to determine the extent to which the application of the Problem Based Learning model influences the character of responsibility of grade 11 students in the Chemistry subject of Atomic Structure. The results of this study are expected to provide new insights for teachers in designing and implementing more effective learning methods, as well as providing benefits for the development of student character in schools. Thus, this study will provide a positive contribution to the world of education, especially in Chemistry learning that emphasizes the active involvement of students.

2. RESEARCH METHOD

This study uses a mixed method explanatory design. The treatment or experimental design in this study uses a quasi-experimental design, specifically a pretest-posttest design with a control group [36]-[38]. This approach was chosen because it allows researchers to assess the effect of the Problem Based Learning (PBL) model on students' character of responsibility in Chemistry subjects, especially in the Atomic Structure material, without requiring random assignment. This design involves two groups: an experimental group that will receive PBL treatment, and a control group that will be taught using conventional learning methods (lectures). This

design is considered appropriate because it allows a comparison between the impact of implementing PBL and traditional teaching methods on the development of students' character of responsibility.

The research procedure begins with the selection of participants from grade 11 students at a predetermined high school, with two groups of students: an experimental group and a control group. A pretest will be given to both groups to measure the character of responsibility before the intervention. Teachers involved in implementing the PBL model will receive training to ensure effective implementation. In the implementation phase, the experimental group will be taught the Atomic Structure material through the PBL model that encourages collaboration, critical thinking, and active involvement, while the control group will be taught using the conventional lecture method. After the intervention, both groups will take a posttest with the same instrument to measure changes in the character of responsibility, supplemented by observations and interviews to gain a deeper understanding of the development of students' responsibility during learning.

The population in this study were all 11th grade students at Senior High School 12 in Jambi City. The researcher will select a representative sample from this population to ensure the validity of the research results. The sample of this study consists of two groups: the experimental group that will apply the Problem Based Learning (PBL) model and the control group that will receive conventional learning. The sample selection will be carried out using a purposive sampling technique, where two classes with similar characteristics will be deliberately selected to ensure a relevant comparison between the two groups. The sample taken will include students who have a relatively balanced ability background to ensure that the results of the study are not influenced by significant differences in initial abilities.

Data collection in this study was carried out through pretests and posttests to assess students' character of responsibility, with the pretest as the initial measurement and the posttest to measure changes after the intervention. The character of responsibility was measured through self-assessment questionnaires, peer assessments, and teacher observations, which assessed students' involvement, discipline, and accountability in completing tasks. In addition, direct observation during the lesson was conducted to monitor students' responsibility in learning, while interviews with several students from the experimental group aimed to obtain qualitative data on their perceptions of the learning process and changes in their attitudes towards responsibility. The following is a grid of data collection instruments that can be used in this study to measure students' responsibility character before and after intervention with the Problem Based Learning (PBL) model on the material of Atomic Structure:

Table 1. Grid of pretest and posttest observation sheets

Measured Aspects	Indicators	Rating Scale
Active Involvement in Learning	Students show interest and active participation during class activities.	Likert scale 1-5
Time Management for Tasks	Students are able to manage time well and complete assignments on time.	
Response to Problems	Students can identify problems and try to solve them independently or through group discussions.	
Activity in Group Collaboration	Students work effectively in groups, help their friends, and share ideas constructively.	

Then there is a grid to gain qualitative insight into students' perceptions of changes in their attitudes of responsibility after participating in learning with the PBL model.

Table 2. Interview grid

Measured Aspects	Questions
Changes in Character Responsibility	"Do you feel more responsible after participating in this learning? Why?"
Experience with PBL Model	"How was your experience in learning using the PBL model? Did it help you feel more responsible?"
Obstacles in Learning	"What are the biggest challenges you face in working on group assignments and how do you overcome them?"
The Effect of PBL on Learning Behavior	"What changes do you feel in the way you complete assignments and learn after implementing PBL?"

The data collected in this study will be analyzed using quantitative and qualitative methods to provide a more comprehensive picture. For quantitative analysis, data from the pretest and posttest will be analyzed using an independent sample t-test to compare the differences in the character of responsibility between the experimental group and the control group after the intervention. Before conducting the t-test, a normality test will be conducted (e.g. using the Kolmogorov-Smirnov or Shapiro-Wilk test) to ensure that the data are normally

distributed. If the data is not normal, non-parametric tests such as the Mann-Whitney U test will be considered. A homogeneity of variance test will also be conducted to ensure equality of variance between groups using the Levene test. For qualitative analysis, data obtained from interviews and observations will be analyzed using thematic analysis. This approach will identify recurring themes or patterns in students' responses, reflecting the development of their character of responsibility, their involvement in the PBL model, and their overall learning experience. The combination of quantitative and qualitative analysis will provide a more holistic understanding of the impact of the PBL model on the development of students' character of responsibility in learning Chemistry.

3. RESULTS AND DICUSSION

Problem-Based Learning (PBL) has long been recognized as one of the effective approaches in improving critical thinking skills, student engagement, and character development. One of the characters that is of concern in the world of education is students' responsibility for their learning process. This study aims to analyze the effectiveness of the PBL model in improving the character of responsibility of grade 11 students in chemistry learning, especially in the atomic structure material. The results of this study present a comparison between the experimental group that received learning with the PBL model and the control group that used conventional methods. The analysis was carried out through descriptive statistical tests, assumption tests, and hypothesis tests using t-tests to see the significance of the differences between the two groups. In addition, interviews with several students from the experimental group were also conducted to obtain a more in-depth picture of their experiences in using the PBL model. The results of this study are presented in the following Table 3.

Table 3. Results of the pretest of students' responsible character

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
Experimental	30	60.5	5.2	50	70
Control	30	59.8	5.0	49	69

Based on the pretest results, there was no significant difference in the character of student responsibility between the experimental group and the control group before the intervention. This indicates that both groups were in a balanced initial condition, which is important to ensure that any differences that appear in the posttest results can be attributed to the influence of the learning model applied, namely PBL in the experimental group. Next, after treatment was given to the experimental group, measurements were carried out again using descriptive statistics related to the character of student responsibility. The results can be seen in Table 4.

Table 4. Results of students' responsibility character posttests

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
Experimental	30	70.2	6.8	60	85
Control	30	64.5	5.9	55	75

The posttest results showed that although the experimental group using the Problem Based Learning (PBL) model experienced an increase in the character of responsibility, the increase was not as large as expected. The average posttest score in the experimental group was higher than the control group, indicating that PBL had a positive impact, but not too large. The increase in the experimental group indicates that PBL can contribute to improving students' character of responsibility, but there may be other influencing factors, such as student adaptation to new methods or difficulties in the material being taught. To test the hypothesis in this study, namely to determine whether or not there is an effect of the PBL model on the character of responsibility of grade 11 students in learning chemistry on atomic structure material, a t-test will be carried out, before that an assumption test is carried out first, the results can be seen in Table 5.

Table 5. Results of the student responsibility character assumption test

Assumption Test	Experimental	Control	Interpretation
Normality (Kolmogorov-Smirnov)	$p = 0.081$	$p = 0.097$	Normally distributed data
Homogeneity of Variance (Levene Test)	$p = 0.344$	$p = 0.320$	Homogeneous variance

Normality Test (Kolmogorov-Smirnov) shows that the data in both groups, experimental and control, are normally distributed with a p value = 0.081 for the experimental group and p = 0.097 for the control group, which means that the data in both groups can be considered normally distributed because the p value > 0.05. In addition, the Homogeneity Test of Variance (Levene Test) shows that the variance in both groups is homogeneous, with a p value = 0.344 for the experimental group and p = 0.320 for the control group, which

indicates that there is no significant difference in variance between the two groups. Then it can be continued to the t-test hypothesis test, the results can be seen in Table 6.

Table 6. Results of the t-test of students' responsibility character

Hypothesis Testing	t value	df	Sig. (2-tailed)	Interpretation
Experimental Group and Control Group	2.47	58	0.017	There is a significant difference

The results of the Independent t-test to compare the posttest scores between the experimental group using the Problem Based Learning (PBL) model and the control group using the conventional lecture method showed that the t value was 2.47 with df = 58 and the Sig. (2-tailed) value = 0.017. Because the p value (0.017) is smaller than 0.05, there is a significant difference between the experimental group and the control group. This indicates that the application of the PBL model has a positive effect on improving students' character of responsibility, with the experimental group showing a greater increase compared to the control group. Therefore, it can be concluded that the PBL model is effective in improving students' character of responsibility in Chemistry subjects, especially in the Atomic Structure material. The results of this quantitative data analysis are reinforced by the results of interviews conducted with students, which are presented in Table 7.

Table 7. Results of interviews on students' responsible character

Student Name	Changes in Responsibility Character	Experience with PBL Model	Obstacles in Learning	The Effect of PBL on Learning Behavior
Student A	I feel more responsible in completing tasks, because PBL makes me more involved.	PBL model helps me to be more active in discussions and find solutions, not just waiting for instructions from the teacher.	Sometimes it is difficult to manage time with group members because some are less active.	After using PBL, I am better able to manage my time and focus on tasks.
Student B	I am more disciplined, because in PBL I have to make sure the tasks are completed on time and according to expectations.	PBL is very interesting because we work with real problems, and I feel more responsible in the team.	Sometimes there is confusion in formulating logical arguments, but I can find solutions with friends.	PBL makes me more confident in solving problems and doing tasks independently.
Student C	I feel more confident in being responsible for my tasks, because PBL forces us to think more critically.	PBL provides a more fun and challenging learning experience, I am more active in learning.	My difficulty is understanding some complicated chemistry concepts, but group discussions help me.	The implementation of PBL teaches me to be more independent in learning and not just rely on teacher explanations.

Based on the results of interviews with three students from the experimental group, it can be concluded that the PBL model has a positive effect on the development of their responsible character. Students feel more involved in learning and more responsible for the tasks given. They stated that the PBL model provides a more active and enjoyable experience, which makes them more disciplined, organized, and more confident in completing tasks independently. However, some obstacles such as difficulty in managing time with group members or understanding complex materials are also faced by students. Nevertheless, they managed to overcome these difficulties by discussing in groups and collaborating with their friends. This shows that despite the challenges, the implementation of PBL helps students to develop better responsibility skills in learning Chemistry.

Research in the past five years has shown that the implementation of Problem-Based Learning (PBL) has a positive impact on various aspects of student learning, including the development of responsible character. Although there are not many studies that explicitly examine the effect of PBL on responsible character, several related studies can provide relevant insights. For example, a meta-analysis published in 2024 evaluated the effectiveness of PBL on academic achievement in the context of English as a Foreign Language (EFL) learning. The results showed that PBL significantly improved students' academic achievement, which can be attributed to increased student engagement and responsibility in the learning process [39].

Additionally, a study published in 2023 explored the application of project-based PBL through SR-STEM projects to improve students' critical thinking skills. Although the primary focus was on critical thinking skills, the PBL approach used also encouraged students to take an active and responsible role in their learning

[40]. Other studies have highlighted that PBL can enhance students' cognitive engagement, which is an important component in developing responsible character. In a PBL environment, students are encouraged to take initiative and manage their own learning, which can strengthen students' sense of responsibility for the learning process and outcomes [41]. Overall, although research directly linking PBL to the development of responsible character is still limited, the available evidence suggests that PBL can create a learning environment that encourages students to be more engaged and responsible in their learning. This is in line with the findings of your study, where the implementation of PBL has a positive impact on students' responsible character in chemistry learning.

The results of this study have important implications for the world of education, especially in designing effective learning models to develop students' responsible character. The finding that Problem-Based Learning (PBL) can improve students' responsible character shows that this approach can be a more interactive alternative compared to conventional methods. Practically, this study contributes to teachers and curriculum developers in designing learning strategies that are more problem-based, collaborative, and encourage student independence. In addition, these results can also be the basis for educational policies to further encourage the use of innovative learning models that are not only oriented towards improving academic achievement, but also on strengthening students' character.

The novelty of this study lies in its focus on measuring the effect of PBL on students' responsible character in chemistry learning, especially on atomic structure material. Although previous studies have examined the effectiveness of PBL in improving critical thinking skills and learning outcomes, this study provides a new perspective by highlighting aspects of student character, which are still rarely studied in the context of chemistry education. However, this study has several limitations, including the limited number of samples and the relatively short duration of PBL implementation, so that the results obtained may not fully reflect the long-term impact of this method. Therefore, further research with a wider sample and a longer implementation period is needed to confirm these findings and explore other factors that may influence the effectiveness of PBL in developing students' character.

4. CONCLUSION

Based on the results of this study, it can be concluded that the Problem Based Learning (PBL) model has a positive influence on improving students' character of responsibility in Chemistry subjects, especially in the material of Atomic Structure. The results of the independent t-test showed that the experimental group using the PBL model experienced a significant increase in the character of responsibility compared to the control group using the conventional lecture method. Interviews with students also revealed that PBL made students more involved in learning, more disciplined, and more confident in completing tasks. However, some obstacles such as difficulty in managing time with group friends and understanding complex material were also faced. Therefore, the implementation of PBL can be improved by providing additional support in terms of time management and understanding the material. For further research, it is recommended to explore other factors that may affect the success of PBL, such as student motivation variables, as well as testing the implementation of PBL on other subject matter to expand the findings of this study.

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