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The Influence of the Project Based Learning Model Integrated Independent Curriculum to Results Learn for Students of Class X Biotechnology Material SMK Islam Al-Azhar Jember

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Abstract: This study aims to analyze the effect of the Project Based Learning model integrated with the Merdeka Curriculum on the learning outcomes of Grade X students in Biotechnology material at SMK Islam Al-Azhar Jember. The study employed a quasi-experimental approach with a pretest-posttest non-equivalent control group design. The sample consisted of 34 students who were given pretests and posttests to measure their biotechnology learning outcomes, using a learning outcome test as the instrument. The results showed a significant improvement in students' learning outcomes after the implementation of the Project Based Learning model integrated with the Merdeka Curriculum, with the experimental group achieving a posttest average score of 89.73, compared to 76.21 in the control group. The N-Gain score for the experimental group reached 0.73 (73%), which is categorized as high, while the control group scored 0.56 (56%). A t-test indicated a significant difference between the two groups ($p = 0.000 < 0.05$). These findings indicate that the Project Based Learning model integrated with the Merdeka Curriculum is proven to be effective in improving Biotechnology learning outcomes.

Keywords: Independent curriculum; Learning outcomes; Project based learning

Introduction

Twenty-first century education demands that students possess critical, creative, collaborative, and communicative thinking skills (Dewi & Arifin, 2024). In an effort to address challenges in the field of education, the Indonesian government has initiated the Merdeka Curriculum as an educational approach that emphasizes differentiated learning, character development, and competency enhancement through context-based projects (Kemendikbudristek, 2023). This curriculum provides space for teachers and students to develop a more flexible, meaningful, and student-centered learning process tailored to individual needs (Indarta et al., 2022). Although the Merdeka Curriculum has been implemented in Indonesia's education system, instructional models that are integrated with this curriculum have not yet been thoroughly studied. This study aims to examine the effectiveness or impact of learning models integrated with the Merdeka Curriculum as an innovation in instructional reform to improve the quality of education in Indonesia.

This study presents several significant aspects of novelty. By directly integrating the Project Based Learning model into the framework of the Merdeka Curriculum at the vocational high school (SMK) level (Erlangga et al., 2024), it adopts an approach that has been rarely explored in previous research. In the context

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of biology education at the SMK level, biotechnology is one of the subjects in Biology that is both applicative in nature and requires conceptual understanding as well as science process skills (Oba & Yildirim, 2021). At SMK Al-Azhar Jember, the biology teacher reported that students struggled the most with the Biotechnology topic, with 57.6% of students failing to master the material. Traditional teaching methods that rely on textbook-based instruction lack the interactive and visual elements necessary to support deeper understanding. Previous efforts to improve learning outcomes included lectures supplemented by textbook reading, but this method has not been sufficient to overcome students' learning difficulties.

A needs assessment and interviews with teachers at this school revealed an urgent need for innovative, engaging, and research- or project-based learning models to bridge the gap between theoretical knowledge and practical understanding (Sumilat et al., 2023). One promising approach to enhance biology learning is the development of a learning model that aligns with the characteristics of student pancasila and students' needs. The Project Based Learning model is one such approach that aligns with the spirit of the Independent Curriculum.

The Project Based Learning model is an innovative instructional approach that positions students as active agents in completing real-world projects related to their daily lives (Syawaludin et al., 2022). This model emphasizes students' active engagement in designing, developing, and completing learning projects based on real-life problems (Nurhidayah et al., 2021). Project Based Learning has been proven effective in enhancing critical thinking skills, learning independence, and students' collaborative abilities (Sarjani et al., 2023). Moreover, it offers authentic and meaningful learning experiences by integrating theoretical concepts with hands-on practice in the field. Unlike conventional learning models that are teacher-centered and dominated by lectures and assignments—often emphasizing direct mastery of material and relying heavily on memorization (Jafar, 2021). Project Based Learning captures students' attention and sustains their interest throughout the learning sessions. Research has shown that well-designed learning models significantly improve information retention and learning motivation (Sophian et al., 2025).

This study addresses the gap in biology education at vocational high schools (SMK) by implementing the Project Based Learning model integrated with the Merdeka Curriculum, specifically in the Biotechnology topic**.** Through this approach, students not only learn biotechnology concepts theoretically but also actively engage in simple research-based projects, such as producing probiotic products (Qosimah et al., 2023). This approach is important as it combines project-based learning with the values of the Pancasila student profile, thereby enhancing student engagement, creativity, and practical understanding. By providing contextual and meaningful learning experiences, this model promotes scientific literacy and prepares students for future academic challenges or entry into the workforce (Rahmadhni & Chatri, 2023).

In summary, this study is important for several reasons. First, it fills a gap in educational practice by developing a Project Based Learning model integrated with the Merdeka Curriculum for Biotechnology material, which has rarely been optimally implemented in vocational high schools. Second, it addresses the challenges faced by vocational students in understanding biotechnology concepts through conventional learning by introducing a project-based approach that involves real exploration and hands-on activities. Third, it offers a model that integrates the principles of the Merdeka Curriculum with project-based learning practices, demonstrating how Project Based Learning can serve as a bridge between theory and practice in science education. Ultimately, this study aims to enhance both the quality of the learning process and outcomes, while also fostering students' interest and scientific literacy in biology, particularly in the field of biotechnology (Kuway et al., 2023).

In conclusion, this study bridges the gap between scientific research and educational practice by developing a Project Based Learning model integrated with the Merdeka Curriculum, using a biotechnology project as the learning context. This approach not only enriches the learning process but also addresses pedagogical challenges faced by vocational school students in understanding biotechnology concepts. The expected outcomes of implementing this Project Based Learning model include increased student engagement, deeper conceptual understanding, and the use of project-based learning materials that support differentiated instruction (Alia & Mulyono, 2025). Thus, this research contributes to improving the quality of biology education and provides evidence that integrating Project Based Learning into the Merdeka Curriculum can create meaningful and contextual learning experiences (Susilawati et al., 2017).

Method

This study employed a quasi-experimental approach using a pretest-posttest non-equivalent control group design (Zhao et al., 2023). This design involves two groups: an experimental group and a control group. Both groups were given a pretest before the intervention, with the experimental group receiving the treatment, while the control group did not. Afterwards,

both groups were given a posttest to measure the effect of the intervention.

Table 1. Pretest-posttest non-equivalent control group

Pretest	Experience	Posttest
O1	X1	O3
O2	X2	O4

(Sugiyono, 2020)
Explanation:
O1, O2: before observation, pretest
X1, X2: control, experiment
O3, O4: after observation, posttest

This research was conducted at SMK Islam Al-Azhar Jember, located in Karang Bireh Village, Sumber Lesung, Ledokombo, Jember. The study population consisted of 68 students divided into two classes. To test the effect of the learning model, the population was randomly divided into two groups: the experimental class and the control class. This division aimed to maintain internal validity and avoid selection bias. The sampling technique used was total sampling, meaning all members of the population who met the criteria were included as the sample (Sugiyono, 2020). The total number of respondents used was 34.

The research instrument included a learning outcome test consisting of 20 objective questions that had been tested for validity and reliability. The Pearson correlation coefficient values ranged from 0.348 to 1, all of which exceeded the r_{table} value of 0.338 (for N = 34), indicating that all items were valid. A reliability test was also conducted to assess the consistency of the instrument in measurement. Based on the results, a Cronbach's Alpha value of 0.928 was obtained for the 20 items, indicating a very high level of reliability, as it exceeded the minimum standard of 0.70. It can be concluded that the instrument is highly reliable and suitable for use.

The observation sheet was used to systematically evaluate the implementation of the Project Based Learning model in the Biotechnology learning process (Hauko et al., 2025). This instrument was designed to observe learning activities based on the main stages of the Project Based Learning model integrated with the Merdeka Curriculum, including the introduction, assessment, core activities following the Project Based Learning syntax integrated with the Merdeka Curriculum, and the closing phase (Rehani & Mustofa, 2023). The observed indicators included lesson openings, pretest administration, group formation, presentation of trigger questions, project planning, scheduling of project implementation, group activity monitoring, project testing and presentation, as well as reflection and evaluation at the end of the lesson (Farhin et al., 2023).

Indicators were assessed using a 4-point Likert scale: 4 (very good), 3 (good), 2 (poor), and 1 (very poor), with a descriptive rubric provided for each score to ensure that observers could give objective and consistent ratings (Simamora, 2022). Observations were conducted by the researcher, and to ensure the quality of the instrument, the content validity of the observation sheet was tested by educational experts. The reliability of the instrument was assessed through inter-rater reliability testing, which demonstrated consistency in observation results between observers. Thus, this observation sheet meets the feasibility criteria for use in research on the implementation of project-based learning.

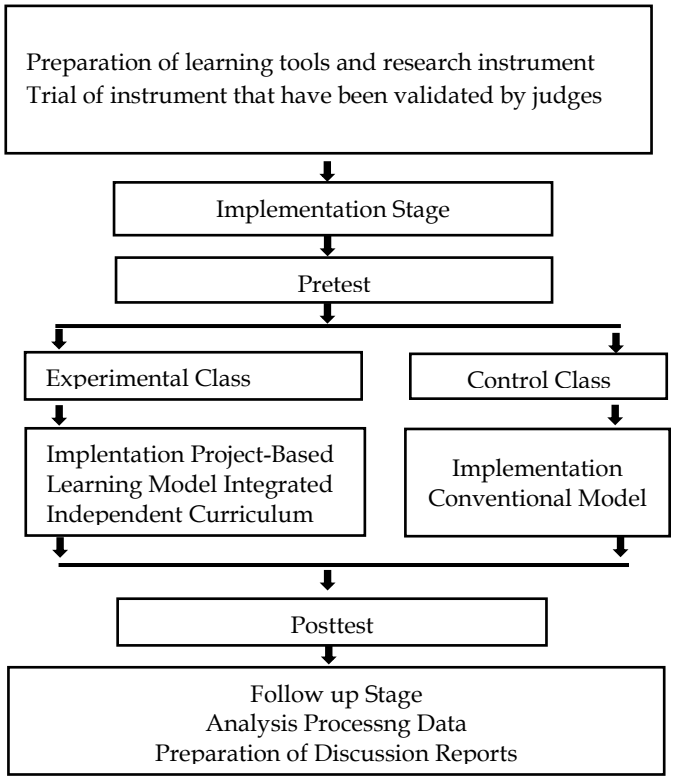

Figure 1. Reserch flow

Student learning outcome data were collected through pretests and posttests administered before and after the intervention. Data analysis was conducted by first testing the statistical assumptions. The normality test was used to determine whether the collected data were normally distributed, using the Kolmogorov-Smirnov test. A variable is considered normally distributed if the significance value is greater than 0.05. The homogeneity test was performed to assess the variance between the two groups using Levene's test. Subsequently, to test the hypothesis regarding the effect of the Project Based Learning model integrated with the Merdeka Curriculum on learning outcomes, an independent t-test was conducted with a significance level of 0.05.

Table 2. N-Gain assessment indicators

Score N-Gain	Cryteria
N-Gain > 0.7	Hight
0.7 < N-Gain < 0.3	Medium
N-Gain < 0.3	Low

In addition, the N-Gain score was calculated to measure the level of improvement in each student's learning outcomes individually. All statistical analyses were conducted using SPSS. With this design and procedure, the study is expected to provide a valid and reliable overview of the effectiveness of the Project Based Learning model integrated with the Merdeka Curriculum on student learning outcomes.

Result and Discussion

Result

This study is a quantitative research using a quasi-experimental design, presenting findings on the effect of the Project Based Learning model integrated with the Merdeka Curriculum on student learning outcomes. The results of the data analysis include the frequency distribution of respondents based on their pretest and posttest scores following the implementation of the Project Based Learning model integrated with the Merdeka Curriculum (Mughni & Sari, 2024).

Table 3. Implementation of pretest scores of the project based learning model integrated with the independent curriculum

Pretest score	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
15	2	5.9	5.9	5.9
20	2	5.9	5.9	11.8
25	3	8.8	8.8	20.6
30	3	8.8	8.8	29.4
35	4	11.8	11.8	41.2
40	3	8.8	8.8	50.0
45	4	11.8	11.8	61.8
50	1	2.9	2.9	64.7
55	3	8.8	8.8	73.5
60	3	8.8	8.8	82.4
65	2	5.9	5.9	88.2
75	3	8.8	8.8	97.1
80	1	2.9	2.9	100.0
Total	34	100.0	100.0	

Based on Table 3, the frequency distribution of respondents according to their pretest scores in biology learning outcomes is as follows: a score of 45 with 4 respondents (11.8%), 35 with 4 respondents (11.8%), 25 with 3 respondents (8.8%), 30 with 3 respondents (8.8%), 40 with 3 respondents (8.8%), 55 with 3 respondents (8.8%), 60 with 3 respondents (8.8%), 75 with 3 respondents (8.8%), 15 with 2 respondents (5.9%), 20 with 2 respondents (5.9%), 65 with 2 respondents (5.9%), 50 with 1 respondent (2.9%), and 80 with 1 respondent (2.9%).

Table 4. Implementation of post-test scores of the project based learning learning model integrated with the independent curriculum

Posttest score	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
35	1	2.9	2.9	2.9
40	1	2.9	2.9	5.9
45	1	2.9	2.9	8.8
50	1	2.9	2.9	11.8
55	1	2.9	2.9	14.7
60	9	26.5	26.5	41.2
65	1	2.9	2.9	44.1
75	1	2.9	2.9	47.1
90	3	8.8	8.8	55.9
95	12	35.3	35.3	91.2
100	3	8.8	8.8	100.0
Total	34	100.0	100.0	

Table 4 shows the frequency distribution of respondents based on posttest scores in biology learning outcomes: a score of 95 with 12 respondents (35.3%), 60 with 9 respondents (26.5%), 100 with 3 respondents (8.8%), 90 with 3 respondents (13.3%), 88 with 4 respondents (8.8%), 35 with 1 respondent, 40 with 1 respondent, 45 with 1 respondent, 50 with 1 respondent, 55 with 1 respondent, 65 with 1 respondent, and 75 with 1 respondent—each representing 2.9%.

Table 5. Data normality test pretest – posttest implementation of integrated project based learning model of independent curriculum

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized residual
N		34
Normal parameters[a,b]	Mean	.0000000
	Std. deviation	16.24220472
Most extreme Differences	Absolute	.200
	Positive	.123
	Negative	-.200
Test Statistic		.200
Asymp. Sig. (2-tailed)[c]		.116

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.

Based on Table 5, the research results show that the data on learning outcomes before (pretest) and after (posttest) in biology learning are normally distributed, as indicated by the p_{value} (0.116) > 0.05.

Based on Table 6, the significance value based on the mean is 0.630, based on the median is 0.657, based on the median with adjusted degrees of freedom is 0.657, and

based on the trimmed mean is 0.622. Therefore, it can be concluded that the significance values of the learning outcomes in the experimental and control classes exceed 0.05, indicating that the variance of the biology learning outcome data in both the experimental and control classes is equal or homogeneous.

Table 6. Homogeneity of pretest posttest data implementation of the project based learning model assisted by the independent curriculum

Test of homogeneity of variance	Levene statistic	df1	df2	Sig.
Based on Mean	.234	1	66	.630
Based on Median	.199	1	66	.657
Based on Median and with adjusted df	.199	1	65.89	.657
Based on trimmed mean	.245	1	66	.622

N-Gain Score Test

Based on Table 7, the calculated N-Gain Score for the experimental class shows an average N-Gain value of 0.73 (73.0%). This result falls into the category of highly effective. From the findings, it can be concluded that the Project Based Learning model integrated with the Merdeka Curriculum has an effect on the learning outcomes of Grade X students at SMK Al-Azhar Jember, Jember Regency, categorized as effective. This is indicated by the N-Gain value of the experimental class being higher than that of the control class (N-Gain = 0.73 > 0.52).

Table 7. N-Gain

Parameters	Class	N	Min	Max	Mean	Std. Deviation
N-Gain Score	Pretest	34	0.32	1.00	0.73	0.23
N-Gain Persent	Posttest	34	31.58	100.0	73.00	22.79
Valid N (Listwise)		34				

Table 8. T-test calculation results

		Levene's test for equality of variances		T-test for equality of means					95% Confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. Error difference	Lower	Upper
Learning outcomes	Equal variances assumed	3.701	.059	-10.771	66	.000	-52.647	4.888	-62.407	-42.888
	Equal variances not assumed			-10.771	65.822	.000	-52.647	4.888	-62.407	-42.887

The research results indicate an improvement in student learning outcomes on the topic of Biotechnology after the implementation of the Project Based Learning model integrated with the Merdeka Curriculum. Based on the results of the T-test on the post-test data, a significance value of p (0.000 < 0.05) was obtained, indicating a significant difference between the learning outcomes of the experimental and control groups.

The average post-test score of students in the experimental group was 89.73, while the control group only reached 76.21. This shows that the Project Based Learning approach integrated with the Merdeka Curriculum has a positive impact on students' mastery of Biotechnology concepts. Moreover, this significant improvement is also reflected in the higher N-gain score of the experimental group compared to the control group, with a percentage of 73%, reinforcing the conclusion that this approach significantly enhances learning outcomes.

Discussion

Schools that implement biotechnology learning play a crucial role in improving student learning outcomes, particularly in understanding scientific concepts in an applied manner (Utari et al., 2024). Learning can begin with simple practicum activities. These activities not only clarify concepts but also encourage students to be actively engaged in the learning process and better understand the application of biotechnology in daily life (Aisa et al., 2023).

To support the improvement of student learning outcomes, teachers need to design interactive and contextual learning models and media so that students can more easily understand biotechnology material. Furthermore, improving learning outcomes is key to meeting the challenges of 21st-century education, which demands deep understanding as well as critical and scientific thinking skills (Chusna et al., 2024).

In this study, the researcher employed a quantitative method with a quasi-experimental approach, enabling the collection of student learning outcome data before and after the implementation of the Project Based Learning model integrated with the Merdeka Curriculum (Nurhadiyati et al., 2020).

The study sample consisted of 34 tenth-grade students at SMK Islam Al-Azhar Jember. The results showed that the implementation of the Project Based

Learning model integrated with the Merdeka Curriculum had a significant effect on student learning outcomes. These findings are in line with previous research by Rafik et al. (2022) and Priyatno (2025), which stated that Project Based Learning can enhance conceptual understanding, critical thinking skills, and student motivation, as it positions students as active participants in the learning process.

Based on Table 3, the distribution of pretest scores shows that most students had varied initial understanding, with the highest frequency of scores in the mid-range of 35 and 45, each representing 11.8%. This indicates that before the treatment, students had relatively homogeneous but suboptimal prior knowledge in mastering biotechnology concepts.

After the implementation of the Project Based Learning model integrated with the Merdeka Curriculum, a significant change occurred as shown in Table 4. The posttest score distribution was dominated by high scores—95 accounted for 35.3% and 60 for 26.5%—indicating improved student understanding. Only a small proportion of students remained in the low score category (≤ 55). This reflects the effectiveness of the Project Based Learning model in enhancing student learning outcomes.

Prior to that, to ensure the validity of the collected data, normality and homogeneity tests were conducted (Daga et al., 2024). The normality test results, as presented in Table 5, showed that the learning outcome data were normally distributed with a significance value of 0.116 (> 0.05). The homogeneity test in Table 6 further confirmed that the variance between the experimental and control groups was homogeneous ($p > 0.05$), allowing the use of parametric tests.

This improvement in learning outcomes can be explained by the characteristics of Project Based Learning, which emphasizes disciplinary concepts and principles, involves students in problem-solving (Hasri, 2021), and encourages them to actively manage projects related to biotechnology applications, such as probiotic production (Lingga et al., 2022). Probiotic-making projects directly enhance students' understanding of biotechnology because they engage in real-world, experience-based learning. Through these activities, students not only grasp biotechnology concepts theoretically but also observe and apply the fermentation process firsthand, which is part of biotechnology.

When students produce probiotics, they interact directly with Lactobacillus microorganisms, which play a crucial role in biotechnological processes (Ameilia et al., 2022). This experience helps them connect concepts such as microbial metabolism, enzyme production, and environmental conditions affecting microbial activity (Wulandari et al., 2025). Moreover, engaging in projects also fosters critical thinking, experimental design, and drawing conclusions from observations—essential skills in science. By observing the tangible outcomes of their work, students realize that biotechnology is not merely an abstract concept but an applied science with real-world benefits, especially in food and health. This contextual and applied approach makes learning more meaningful, increases motivation, and strengthens students' retention of biotechnology material (Yanti et al., 2023).

This is further supported by the N-Gain test results in Table 7, which show a significant increase in learning scores. The average N-Gain for the experimental group was 0.73, categorized as "high" or "highly effective," compared to 0.52 in the control group, based on Hake's classification (Azka et al., 2019). This demonstrates that the application of the Project Based Learning model integrated with the Merdeka Curriculum significantly improved students' understanding of biotechnology compared to conventional methods used in the control class. This finding is reinforced by the T-test results in Table 8, which show a significant difference in posttest scores between the experimental and control groups, with a significance value of $p = 0.000$ (< 0.05). The notable average posttest score difference—89.73 for the experimental group and 76.21 for the control group—confirms that Project Based Learning not only improves quantitative learning outcomes but also deepens conceptual understanding in biotechnology. Overall, this project-based approach has proven effective both statistically and practically, as reflected in the score distribution, N-Gain values, and T-test results. These findings align with constructivist theory, which emphasizes the importance of students' active involvement in contextual learning to improve conceptual understanding and overall learning outcomes (Azzahra, 2025).

Observations during the learning process also indicated that the implementation of the Project Based Learning model integrated with the Merdeka Curriculum was carried out very well. All core stages of the syntax were applied, with an average implementation score of 3.6. These findings reinforce the quantitative results, which showed significant increases in posttest scores and N-Gain. Students' active involvement in projects demonstrates that learning impacts not only cognitive aspects but also fosters critical thinking skills and attitudes (Sari, 2018). The discussion and exploration processes within the projects allowed students to construct knowledge contextually and meaningfully, directly contributing to improved learning outcomes (Novita et al., 2024). Thus, the qualitative and quantitative data in this study complement each other in demonstrating the

effectiveness of the Project Based Learning model integrated with the Merdeka Curriculum.

In conclusion, learning through the Project Based Learning approach integrated with the Merdeka Curriculum has been proven effective in improving student learning outcomes. This improvement occurred both statistically and practically, as reflected in score distribution, N-Gain values, and T-test results. These findings are consistent with constructivist theory, which states that active student engagement in contextual learning can enhance conceptual understanding and overall learning outcomes (Maksum & Purwanto, 2022).

Conclusion

The implementation of the Project Based Learning model integrated with the Merdeka Curriculum has proven to be effective and has a significant positive impact on the learning outcomes of tenth-grade students on biotechnology material at SMK Islam Al-Azhar Jember. The improvement in learning outcomes is evident from the difference in posttest scores between the experimental and control groups, as well as an N-Gain score of 0.73, which falls into the high category. In addition to enhancing conceptual understanding, the Project Based Learning model integrated with the Merdeka Curriculum also fosters the development of 21st-century skills such as creativity, collaboration, and independence—aligning with the objectives of the Merdeka Curriculum and the strengthening of the Profil Pelajar Pancasila. The application of the Project Based Learning model integrated with the Merdeka Curriculum has been shown to be effective in improving students' learning outcomes in biotechnology. This approach not only strengthens conceptual understanding through active involvement in practical projects, such as probiotic production, but also encourages the development of critical thinking and problem-solving skills. The pretest and posttest results indicate a significant increase in student scores, as evidenced by an N-Gain score of 0.73 (high category) compared to 0.52 in the control class, and a T-test result showing statistical significance with $p = 0.000$ (< 0.05). These findings demonstrate that Project Based Learning can create meaningful and contextual learning. Therefore, it can be concluded that project-based learning, when developed according to the principles of the Merdeka Curriculum, is a relevant and impactful strategy for improving learning outcomes, conceptual understanding, and student engagement in 21st-century learning.

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Conceptualization, K.A., D.S.S., and H.R.P.; methodology, formal analysis, data curation, and writing original draft preparation, K.A.; investigation, K.A. and D.S.S.; resources, writing—review and editing, and validation, D.S.S. and H.R.P.; Visualization, H.R.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The author declares no conflict of interest.

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