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Enhancing Learning in Biomedicine through Research-based Learning: Empowering Students for Future Success

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Abstract
Background: Research-based Learning (RBL) is globally recognized for improving scientific literacy and critical thinking. Providing authentic research experiences in undergraduate education, RBL enhances student confidence in scientific contribution, improves subject understanding and retention, and fosters the acquisition of technical and soft skills.

Aim: Assess RBL's impact on Biomedical Sciences students' engagement and skills.

Methods: Seventy-six 3rd-year Biomedical Sciences students completed a 5-week Research in Biomedicine course, going to the laboratory, and attending workshops on scientific writing, reference management, and poster creation. They presented their findings through written and oral presentations at a congress.

Results: Survey results showed positive feedback from both the students and tutors: 100% student satisfaction, 94% reported skill development, and 88-94% of tutors noted improved motivation, teamwork, and problem-solving abilities.

Conclusions: The study confirms RBL's efficacy in improving learning, critical thinking, and teamwork in biomedical education. It advocates its broader application, empowering students worldwide.

Keywords: *Research-based learning; pedagogical strategies; active teaching-learning; biosciences.*

1. Introduction

The growing importance of changing a culture where students are passive receivers of information to one where they become active inquirers has been recognized in the university ecosystem since the end of the past century. Active teaching and learning methodologies, particularly Research-Based Learning (RBL), have gained recognition, marking a shift from a traditional teacher-focused to a student-focused approach, where students are empowered with authentic research experiences during undergraduate education. So far, several universities have successfully implemented RBL to replace traditional “cookbook” labs (Noguez & Neri, 2008; Saptuti Susiani et al., 2018; Stanfield et al., 2022). By immersing students in real scientific research environments, they not only deepen their understanding of the subject matter because they are applying concepts learned in the courses to real-life situations boosting academic performance, but also enhancing their critical thinking and problem-solving abilities. Students are more likely to invest in their learning when they are actively involved in the research process. Indeed, RBL leads to increased student engagement, motivation, and confidence in contributing to science. It cultivates essential skills, such as communication in science, dealing with uncertainty, independence, teamwork, and organizational and time management skills. It is also advantageous for the teachers as they build strong student-teacher relationships through collaborative design. Moreover, RBL promotes lifelong learning as it can help students develop a passion for learning and a curiosity about the world around them (Auchincloss et al., 2014; Buffalari et al., 2020; Lefurgy & Mundorff, 2017; Meyer et al., 2023; Seymour et al., 2004; Uyanık, 2016). Nonetheless, implementing RBL in the first cycle faces challenges such as teacher training, time constraints, limited resources, logistical issues, and the cost of research supplies for many students. Resistance to change and the need for new assessment methods further complicates the integration process. Proposed solutions include creative resource allocation and cost-efficient models. The students might not be prepared for the level of independence and responsibility required for RBL experiences, so teachers may need to provide additional support and guidance (Corrales et al., 2020; Stanfield et al., 2022). This paper focuses on a case study implementing RBL in a "Research in Biomedicine" course for 3rd-year Biomedical Sciences students. The study aimed to assess the impact of RBL on student engagement, critical thinking, and teamwork skills, through laboratory projects and scientific communications. Moreover, the project seeks to foster collaboration among faculty members, involve students in curriculum design, collect evidence on pedagogical practices, and share the results with the academic community. Ultimately, this initiative aspires to encourage the transfer of knowledge to similar teaching contexts, creating a ripple effect of transformative education and enriching the educational landscape.

2. Methods

2.1. Context and study participants

In the academic year 2022/2023, 76 students from the 3rd-year of the 1st cycle degree in Biomedical Sciences enrolled in the course “Research in Biomedicine”, from February to June of 2023. Each group worked on a different research topic, voluntarily assigned by a supervisor, for 5 weeks (1.5 days/week) under the mentorship of 28 experienced investigators. Students were asked to form groups of 3 and choose the top 3 preferred project topics, in priority order. For the topics chosen by more than one group, a ruffle was made. The research topics were chosen based on ongoing projects of the proponent investigator. Several fields of study were covered, namely human reproduction, pharmacology, virology, and bioinformatics. The students also had parallel lectures on how to elaborate a short communication and a poster, and how to manage references and bibliography using Mendeley. This was designed to help students develop scientific writing and communication skills. Lastly, they also did an exam on biosafety.

2.2. Evaluation

2.1.1. Student assignments

Unconventional assessment methods (not written exams) were employed to immerse students closer to the researcher's environment **(Figure 1**). At the beginning of the course, a biosafety written test was conducted to ensure student´s knowledge of laboratory rules, and therefore give them clearance to go to the laboratory. Throughout the semester the involvement and attendance as well as the performance in the experimental activities (planning, execution, and analysis of the results) were continuously evaluated. In the final week, students had to submit a final report, which could be either a short communication or a mini-review, and then present a poster showcasing their research while practicing communication skills in a congress. This event took place in half a day, including a coffee break, and was open to the academic community. Each group was evaluated by a jury composed of 3 senior researchers or PhD students. The best poster was awarded, for extra motivation, with vouchers for a bookstore.

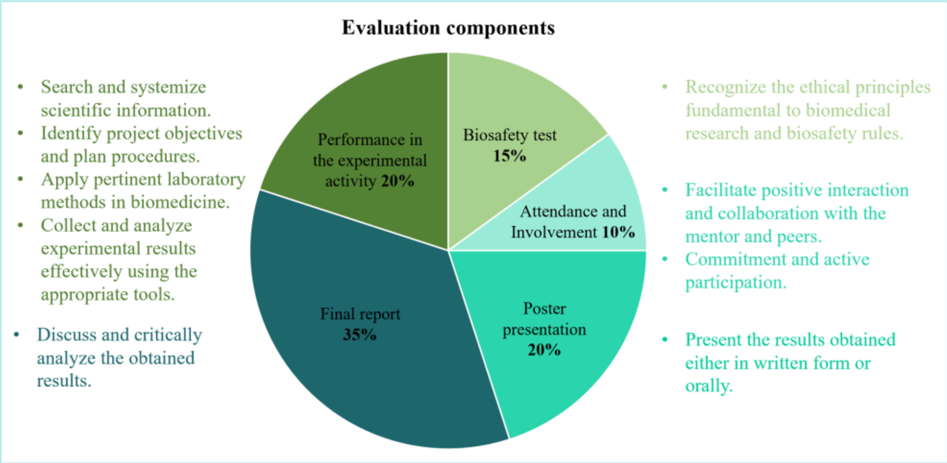

Figure 1. Components evaluated in this course, including their weight and learning outcomes.

2.1.2. Data collection and analysis

Two satisfaction surveys were conducted to collect feedback from students and tutors, aiming to evaluate the RBL methodology and the overall functioning of the course. Out of 76 students, 34 responded to the survey, and 17 out of 28 tutors provided feedback. Utilizing a 5-point Likert scale (1 for 'totally disagree' to 5 for 'totally agree'), the satisfaction surveys also included an open-ended feedback section, so that they could complement their opinion. Positive and negative feedback from students and tutors were categorized, and the frequency of similar ideas was noted. Ethical consent was obtained to perform the present study. For effects of analysis of results, the frequency of "4" (agree) and "5" (totally agree) were summed and considered to be the total of people that agree. IBM SPSS Statistics (version 29) was used for summary statistics (median, standard deviation, frequency) and to calculate Cronbach's alpha coefficient to assess the internal consistency of the survey. A graphical representation of student and tutor opinions (percentage vs. agreement level) was created using Excel.

3. Results and discussion

3.1. Student´s survey

A survey was conducted to assess the level of agreement in terms of RBL benefits, methods of evaluation, course dynamics, overall functioning, and expectations. The mean score for all 24 questions was 4.211 out of 5. The Cronbach's alpha is 0.812, indicating good reliability of the survey outcomes. Key insights (**Figure 2**) include high satisfaction with having several assessment methods (97.1%), and the clarification the students got for their future, in terms of graduate studies and professional careers (79.5%).

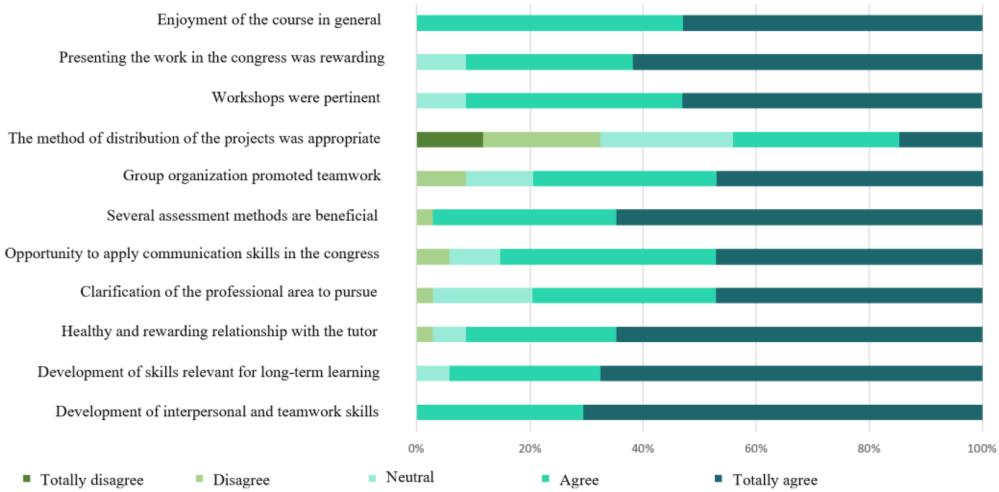

Figure 2. Main results from the student´s survey.

They also enjoyed having workshops (91.2%) and presenting their work in a congress (91.2%), which also allowed them to apply communication skills (85.3%). The congress was deemed a success in showcasing students' work (**Figure 3**).

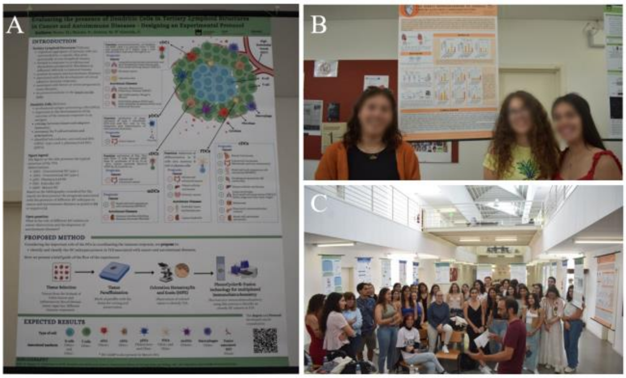

Figure 3. Congress proof-of-concept. (a) winning poster, (b) a group with their poster, (c) announcement of the winning poster prize, and final considerations.

Notably, 100% of students agreed on developing interpersonal and teamwork skills. All of them enjoyed the course in general. Qualitative comments highlighted the course's adaptability for each student's interest, and motivation boost, and suggestions for improvements were given, including project selection methods, standardization between groups, and an increase in course workload. Most students expressed satisfaction with the course, highlighting enjoyment, motivation, and skill development in interpersonal, teamwork, and long-term learning. They liked having the opportunity to be in a research laboratory and acknowledged that RBL is adapted to each person, as each student can choose the research area that interests them most. In the biomedical sciences bachelor, the students have a total of 5 courses that happen in teaching laboratories, where they just follow a protocol and then have to write a report about it. While this might help them to learn technical skills, they are not developing other essential skills like problem-solving skills, contrary to what happens with RBL. Some students mentioned that their final report could be published. While it is recognized that those reports are not deep enough to be publishable, an opportunity could be given to the students who desire to improve them. The students also proposed having more workshops, namely on data analysis platforms. Students' desire for research paper writing and additional workshops indicates a proactive approach toward enhancing their learning experience. Indeed, the positive aspects align with the benefits of RBL mentioned in the introduction. However, certain areas require attention and improvement. Challenges were identified in the initial distribution of students to different research projects, leading to disagreements and misunderstandings (frequency in qualitative comments: 4; only 44.1% of the students agree that the method of distribution was appropriate). Student suggestions include individual project choice and using average classification as a tiebreaker. To give the same opportunity to all the students the tiebreaker was a raffle, which did not meet the expectations of a few students. It was also noticed that a few students compromised the project they wanted to work on to be in a team with people they are used to working with. Next year we will discuss the best strategies for the distribution of the topics with the students. Standardization between groups, including laboratory hours, also emerged as a concern (frequency in qualitative comments: 11), emphasizing the need for clearer guidelines. Thus, a guide for the conduct of tutors will be extensively developed for the next academic year, and instead of a single list of indications at the beginning of the course, the tutors will have training. Further improvements include a weekly space for basic training procedures like pipetting and making solutions. Another future implementation will be the creation of a student focus group to promote the exchange of feedback on the course, in terms of difficulties that might need to be solved in time.

3.3. Lab tutor´s survey

For the 17 questions that composed the lab tutor´s survey (**Figure 4**), the mean score was 3.982 out of 5. The Cronbach's alpha is 0.695, suggesting a careful interpretation of the results. Notable findings include high agreement on the course's contribution to improving students' knowledge (100%). Tutors generally perceived students as motivated and committed (94.1%), with positive interactions and a healthy relationship (82.3%). Even though tutors felt that students were willing to learn the laboratory techniques that were proposed and showed problem-solving and teamwork skills (88.2%), only half of them agreed that students showed initiative and autonomy when carrying out the tasks in the laboratory (52.9%), suggesting a need for fostering these qualities in future iterations of the course.

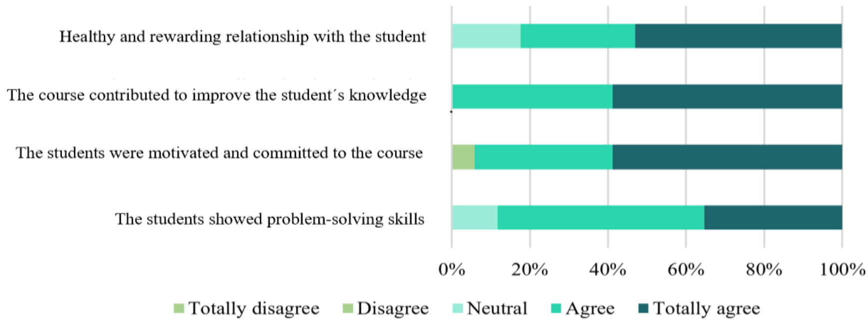

Figure 4. Main results from the tutor´s survey.

Qualitative comments highlighted positive aspects such as effective course operation and opportunities for interaction with motivated students. Improvement suggestions focused on laboratory logistics, due to the presence of many students in the laboratories at the same time, which must be properly scheduled, and basic reagents should be provided for each tutor. Additionally, the students' availability was noted, as they participate in different courses and, it was quite hard to conciliate the different schedules. Concerns about students' maturity and potential interference with parallel tasks suggest the need for interventions to enhance students' readiness for laboratory work. Overall, the positive feedback from tutors, their willingness to continue in their roles (100%), and the acknowledgment of the course's contribution to students' future preparedness underscore the success of RBL in creating a collaborative and engaging learning environment.

3.4. Implications and Future Improvements

The mean final course classification was 18 out of 20, reflecting overall strong performance by students. The findings collected from the surveys have broader implications for advancing RBL practices in the field of biomedical sciences. In order to increase the number of answers to the student survey, next time it will be delivered before the end of the semester. The study highlights the importance of early development of RBL competencies in undergraduate education. Future iterations of the course could benefit from pre-assessment questionnaires to gauge students' initial research competencies. This is particularly important when facing a very heterogeneous group. The students from this bachelor are well prepared to know how to access scientific literature using databases, due to the problem-based learning methodology used in other courses students attend. However, for 1st cycle degrees that don´t offer this kind of preparation at priori, it is advisable to give a workshop on this. The proposed weekly training space for laboratory procedures and the focus group for teacher-student interaction are innovative ideas to further enhance the course. Successive iterations of the course must be analyzed to track its evolution and effectiveness. This approach aligns with the continuous improvement philosophy, allowing for refinement based on yearly feedback.

4. Conclusion

The pedagogical experiment described herein demonstrates the positive impact of RBL on student engagement, critical thinking, and teamwork skills in the context of biomedical sciences, bridging the gap between theoretical knowledge and practical application. Our research findings indicate that the course methodologies effectively promoted RBL benefits. However, areas for improvement remain, particularly regarding project distribution methods and standardization between groups. These insights can be used for improvements and adaptations to refine the course's design and implementation, ensuring that students' satisfaction is maximized, and their learning outcomes are achieved. Despite the challenges, creative solutions and successful examples demonstrate the potential for widespread adoption, paving the way for a future where RBL becomes integral to undergraduate education.

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