African Journal of Educational Studies in Mathematics and Sciences Vol. 20, No. 2. 2024

Effect of Jigsaw Teaching Method on Students' Performance in Biotechnology, their Perceptions of its Benefits and Constraints in its use

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Abstract:

The jigsaw cooperative learning method involves dividing a topic into segments, with each student mastering one part in an expert group and teaching it to their home group. This method fosters collaboration, critical thinking, and mutual accountability, as each student's contribution is essential for the group's overall understanding of the learning concept. Thus, this study explored the effectiveness of the jigsaw method in teaching biotechnology to undergraduates' university students. A mixed-method research design was employed, utilizing both quantitative and qualitative approaches. The intervention involved 40 students, with data collected through tests, Likert scale questionnaires and interview. Quantitative data were analyzed using descriptive and inferential statistics, while qualitative data were thematically analyzed. The findings revealed that students taught using the jigsaw method scored significantly higher than those who received traditional lectures and expressed positive perceptions about the outcomes of the method. The benefits highlighted by students included enhanced communication skills, teamwork, knowledge retention, a fun learning atmosphere, and increased self-esteem. However, challenges such as time constraints and limited guidance were also noted. The study concluded that the jigsaw method significantly improved teaching and learning outcomes in biotechnology. Further research is recommended to explore the impact of this approach on other subjects at different levels of learning.

Keywords: teaching biotechnology; jigsaw learning method; cooperative learning method; student experiences; .

Introduction

Biotechnology instruction is still inadequate, largely limited to theoretical concepts and lacking depth. This is due to the prevailing teaching approaches, which fail to provide comprehensive and practical understanding (Altiparmak & Nakiboglu, 2009; Ndikumana *et al*., 2024)**.**To enhance the education system, there has been a significant shift, particularly in higher education, from a teacher-centered approach to a learner-centered one, placing students at the heart of the learning process (Costouros, 2020, Elkhidir, 2020). However, it was reported that higher education institutions continued to rely on lectures as their primary instructional method, which is less effective because it does not actively engage students or provide them with greater

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 DOI: https://dx.doi.org/10.4314/ajesms.v20i2.2

control and accountability (Elkhidir, 2020; Hurtado et al., 2012). Learner-centered approach is considered effective to equip scientific undergraduates with transversal competences needed in modern scientific careers which include collaborative and cooperative work, communication skills, critical thinking, solving complex problems, and creativity and social (Arman, 2018). However, the approach does not automatically lead to the effective collaborative learning, which continues to be a challenge (Pervaz Iqbal et al., 2020). Unequal participation, ineffective communication, conflicts and difficult members were experienced by students (Skinner et al., 2015).

The jigsaw cooperative learning technique, a learner-centered approach, is regarded as effective in developing essential transversal competencies in students (Tang, 2023). The jigsaw cooperative learning technique is an instructional strategy where students work in groups to complete different parts of a task or project. Each group member is responsible for learning and mastering a specific portion of the content. After becoming an expert in their assigned section, each member then teaches what they have learned to their group. This method promotes collaboration, ensures that all students participate, and helps them to develop a deeper understanding of the material as they both teach and learn from their peers (Mengduo & Xiaoling, 2010).

The approach was suggested by Elliot Aronson in 1971 and firstly applied by Areston in 1978. It resulted in much success in promoting students' outcomes such as social, conceptual and cooperative skills, and was next developed by Slavin in 1980. Jigsaw technique also makes students actively engaged in the learning process than in the lecture learning process (Jafariyan et al., 2017; Yemi et al., 2018; Dacosta & Fabella, 2023) because it focuses on cooperation (Dhull & Verma, 2019b). The objective of this technique is to study the learning material in small groups, following a structured approach consisting of four detailed steps: planning and preparation, implementation, observation, and reflection, to achieve specific goals (Dhull & Verma, 2019b). The use of jigsaw method has been greatly studied out of our country to equip students with favorable learning outcomes (Halimah & Sukmayadi, 2019). Various studies have also conducted to generate different types of jigsaw (Cochon Drouet et al., 2023). In this study we focused on "jigsaw I" method developed by Aronson et al. (1978).

In this approach, students are divided into small groups called "home groups". The lesson content is broken down into separate segments, with each segment assigned to a different member of the home group. Members of different home groups who are working on the same segment come together in "expert groups". In these expert groups, they discuss, thoroughly understand, and develop their assigned content into teaching materials. Each expert then returns to their home group to teach their segment to their peers (Garcia et al., 2017; Sanchez-Muñoz et al., 2022). The third step involves students evaluating their peers, while the teacher analyzes each student individually using assignments and tests. In addition, students receive individual and group performance comments (Dacosta & Fabella, 2023). Johnson, Johnson and Holubec (1993) proposed five principles for jigsaw strategy namely positive interdependence, face-to-face promotive interaction, individual and group accountability, interpersonal skills and group processing. As stated by Costouros, 2020 "With these principles, a university graduate can be expected to become a long-life learner with a balanced ability of hard skills and soft skills".

Jigsaw was shown to be used at any level of education for any subject as they are content-free approaches (Costouros, 2020). The growing interest in higher education was noticed with the used of jigsaw cooperative learning strategy to increase the quality of education and the quality of graduates (Yatimah et al., 2019). Therefore, it was selected in this study to be used to enhance students' learning outcome in biotechnology. Biotechnology represents a rapidly developing field of recent scientific research and technological advances (Yazici & Altiparmak, 2010). It is taken as difficult to study and that it is taught through traditional teaching ways. Numerous studies agreed on the effectiveness of jigsaw method in teaching a diversity of subjects mostly in Science (Hamadneh, 2017; Jainal & Shahrill, 2021). The current study seeks to investigate whether the jigsaw technique can help students learn topic concepts, to establish students' impressions of the jigsaw method, and to identify the challenges that students may face when implementing the jigsaw method.

Theoretical framework

Constructivism theory, which emphasizes how students actively construct their own ideas, is particularly relevant to research on how effective the jigsaw approach is in teaching biotechnology (Fensham et al., 1994). Constructivism holds that when students are actively involved in their education, they learn more effectively. This is supported by the jigsaw technique, which has students become specialists in several areas of biotechnology before instructing their colleagues. By actively participating, learners are able to create their own knowledge instead of only absorbing it (Cobern, 1993). In addition, the jigsaw technique promotes active learning and collaboration—two essential components of constructivism. Students share their knowledge and put together a comprehensive grasp of biotechnology through group work. Collaboration is in line with the notion that understanding is enhanced via discussion and debate of ideas, and that learning occurs when people interact with one another.

Constructivism backs up the idea that collaborating and exchanging viewpoints can improve learning. Constructivism also encourages introspection and assistance during the learning process. Students can consider what they have learned and how their understanding aligns with the contributions of their peers by using the jigsaw approach. Students' comprehension of biotechnology is strengthened by this reflection (Jaiswal, 2019). In order to help students properly manage their learning duties and integrate information, teachers can also offer scaffolding, or support. This guarantees that students pick up comprehension techniques for difficult subjects like biotechnology in addition to learning the material.

Literature review

The jigsaw approach has become well-known throughout the world for its ability to improve instructional techniques and raise students' academic achievement in a variety of courses and fields (Kardaleska, 2013). Studies carried out in the Philippines in the fields of science and literature, have proven how successful the jigsaw approach is. Particularly, research showed that this method greatly enhances students' interest, comprehension of the subject matter, ability to work cooperatively in a group, and participation levels in addition to their academic achievement. This data highlights the jigsaw method's potential as a formidable educational tool for creating a more productive and engaged learning environment (Jainal & Shahrill, 2021). Saputra et al. (2019) showed that the problems solving skills can also be developed in students through jigsaw learning. Expertise, responsibility, facilitation, and approachability were also promoted. On other side, Ogunleye (2020) confirmed that the

teaching based on jigsaw strategy is effective to help students to understand science concepts and thereby increasing their scores. The improvement in students' understanding of the learning material and learning achievement were also indicated in the study carried out in Indonesia and Nigeria (Khoiriah et al., 2016). The former author also pointed out the increase in student involvement along with the enhancement in team work and autonomy in the learning process.

Other researchers (Al-salkhi, 2015, Espinosa et al., 2019), revealed that applying jigsaw strategy in teaching results into active participation, self esteem, confidence, self-efficacy important in communication and discussion of ideas and worth. Ballen et al. (2017) demonstrated that the active participation induces students to takes ownership over their learning while confidence, self-efficacy correlate with better performance and retention in a discipline. Increase in attention in the course was also noticed in various studies related to the use jigsaw method and shown to enhance students' understanding. On other side, Loh and Ang (2020) suggested that the deep understanding is also a result of learning in small groups. This provides to students a room of effective discussion and helping each other leading to individual success in academic performance and affinity learning as stated by some researchers (Møgelvang et al., 2023). Positive interdependence in small group was also mentioned in the study by Weidman and Bishop (2009) along with individual accountability. The later may due to the eagerness of each of the students to work on the assigned piece of the content which requires full understanding in order to teach it to other group members.

The study conducted by Garcia et al. (2017) showed that using jigsaw method increases students' interaction which promotes the social bond within the group as revealed in the study by Garcia et al. (2017). As a result, each member feels to be integrated in groups and may lead to the sense of belonging, important once working in groups. This happens when each students is shown to be essential which is revealed in personal ego-strength (Surjaw et al., 2013)**.** In undergraduate STEM education, the sense of belonging has been examined as one of many student outcomes of cooperative learning (Furuto, 2017; Wilton et al., 2019). Therefore, higher education should focus on the practices changing it into places of belonging reduced during Covid19 (Lederer et al., 2021)

Generic skills also named 21st century skills applied in various contexts and useful in life were shown to be developed from interaction, a characteristic of jigsaw strategy (Lederer et al., 2021). Those skills were illustrated crucial for lifelong learning and extremely needed by employers (Male et al., 2011). The literature did not also ignore greater social bonds promoted within the group due to interaction. It was concluded that jigsaw strategy in undergraduate STEM education is not only linked to generic skills but also to academic success and positive attitudes (Pilcher et al., 2015). Studies had already pointed out the high weight of active and cooperative approach on learning and interest of students (Loh & Ang, 2020). The jigsaw method was also shown to allow the instructor to act as a facilitator (Pilcher et al., 2015). This helps the students to take part in knowledge generation contrary to traditional method where they were taken as receiver of knowledge transmitted by the instructor.

Biotechnology is considered to be hard to students and mainly taught through lecturing method (Yazici & Altiparmak, 2010; Xue, 2020). Thus, it was worth to apply jigsaw strategy to teach students biotechnology, most especially in their topic about plant

microprogation, for its many impacts including understanding of the subject concepts, easily acquisition and retention of knowledge leading to better results. Up to date, there is no any known research conducted in Rwanda on the use of jigsaw cooperative learning method, which is a gap needed to fill in the course of this study. This study examined the role of jigsaw strategy in undergraduates' sciences students' performance. It also investigated on the perceptions toward the application of strategy as well as the students self perceived benefits from the jigsaw method. Finally, the obstacles students met during the use were also determined.

Research questions

This study was guided by the following research questions:

1. What is the contribution of the jigsaw method on undergraduate science students' performance in biotechnology?
2. What are undergraduate science students' views towards the effectiveness of jigsaw method in learning biotechnology?
3. What are undergraduate science students' self-perceived benefits of jigsaw method in learning biotechnology
4. What are the constraints faced by students while learning biotechnology with jigsaw method?

Methodology

Research Paradigm and design

The present study employed an explanatory sequential design, incorporating both quantitative and qualitative data collection. Data were gathered in two consecutive phases. In the first phase, quantitative data were collected and analyzed, followed by the collection of qualitative data (Creswell & Creswell, 2005). In this context, the qualitative findings provided deeper insights into the quantitative results. The use of multiple data collection methods, known as triangulation, allowed for the examination of data from various sources, thereby enhancing the study's trustworthiness. It is crucial to ensure that the conclusions drawn from these different methods converge on the same point.

Participants

The participants were 40 undergraduate science students specifically from the Department of Biology, Biotechnology option. They were third-year students who voluntarily participated in a teaching and learning process based on the jigsaw method of instruction, in the third trimester during the 2023-2024 academic year. The group consisted of 18 females and 22 males, selected through convenient sampling due to their availability and suitability for this intervention study (Creswell & Creswell, 2005). The University of Rwanda is dedicated to training students in pure sciences, including biotechnology, with the mission of contributing not only to Rwanda's labor market but also to making them globally competitive in the field of biotechnology.

The jigsaw teaching method

The application of the Jigsaw teaching method to biotechnology was carried out through seven two-hour sessions, structured to encourage student collaboration and active engagement. At the start of each session, participants were introduced to the Jigsaw method and the content to be covered. Students were randomly divided into "home groups," each consisting of five members, reflecting the number of topics to be studied. Each member selected a specific topic, and those with the same topic from different home groups formed "expert groups." In these expert groups, students worked collaboratively to research, discuss, synthesize, and prepare learning materials

using various resources. After completing this preparatory phase, students returned to their original home groups to teach their peers, ensuring that all group members understood the entire range of topics(Jeppu et al., 2023). Teachers facilitated the learning process by providing guidance and support throughout the sessions. Each session concluded with an evaluation, reflection, and feedback phase, allowing students to consolidate their understanding and share insights on the learning experience(Dhull & Verma, 2019a).

The Jigsaw teaching method was not a new design by the researchers but was adopted from existing educational research and tailored for biotechnology instruction. Its implementation involved collaboration between researchers and facilitators to adapt the approach to the specific context and learning objectives. In contrast, the lecture-based approach in teaching biotechnology followed a traditional format, where the instructor presented the material directly to students without any group interaction or peer teaching. The intervention group engaged in the interactive and collaborative Jigsaw method, while the lecture-based approach group adhered to the conventional teacher-led instruction. This comparative setup allowed for an evaluation of the effectiveness of the Jigsaw method in enhancing learning outcomes in biotechnology.

Jigsaw teaching method or technique was implemented through seven sessions of two hours each. At the beginning of the class, the participants were introduced to jigsaw method and to the content to cover based on jigsaw-based classes. Then, students were randomly divided into home groups of 5 based on the number of the topics to cover and each member in each group selected a topic to learn. The members having the same topic from different home groups met to form the expert or jigsaw group. In these groups, the role of students was to research, discuss, synthesize and prepared the learning materials in a given time using various resources. After this activity, students returned in their own home groups to teach the material to their peers (Jeppu et al., 2023). During jigsaw teaching and learning process, the teachers closely facilitated the students to optimize students' learning process. Finally, the session ended by an evaluation and concluded with refection and feedback (Dhull & Verma, 2019a).

Validity

The validity of the test, questionnaire and interview guide were checked face to face by the experts in the field of Biology from the University of Rwanda, College of Education (UR-CE) and then reviewed to ensure the relevance of the questions based on the issues under study. Regarding the comprehension and clarity, the statements were subjected to English checking and were again accordingly reviewed to ensure the validity of the study (Roberts & Priest, 2006). The Cronbach-α coefficient was used to measure reliability and was found to be 0.79 which proves the consistence and stability of results from the instrument.

Data Collection tools and procedure

Three data collection tools were employed: a test, a survey and interview. First, students completed a written test at the end of the application phase. This test, which featured 12 questions based on Bloom's taxonomy, was designed to evaluate the effectiveness of the jigsaw technique on undergraduates' grasp of scientific concepts. Another group of students, who had attended lecture-based classes, took the same set of questions, enabling a comparison of test scores. This approach helped to assess students' understanding of the jigsaw method. Following this, a

questionnaire was administered to collect quantitative data on students' experiences with the jigsaw technique. The questionnaire consisted of two main sections: one with closed-ended questions and the other with an open-ended question.The first part was designed and included different statements from the review of the various literature reviewed to suit our investigation (Daniel & Gonzales, 2016 and Nusrath et al., 2019). It was used to collect undergraduates' science student perception on the implementation of jigsaw method and to identify undergraduates' science student elements self-perceived as benefits of jigsaw method in relation to its principles. For the closed question regarding the implementation of the jigsaw method, a five-point Likert scale was utilized, with 1 representing "strongly disagree" to 5 representing "strongly agree." The open-ended question section, on the other hand, explored the constraints encountered during jigsaw sessions. After some instructions, the surveys were filled and collected after the last session of the course. An interview guide was developed and included questions aiming complementing, clarifying and extend the understanding of the results obtained in quantitative phase. The students were purposively selected and interviewed into two groups of 5. The questions explored student's opinions on jigsaw learning sessions in-depth along with its impact on their understanding of the subject concepts. The answers were audio tape- recorded and accurately transcribed.

Employing multiple data collection tools such as tests, surveys and focus group interview contributed to the study's reliability. Additionally, returning the interview transcripts to participants allowed for the correction of any errors based on their feedback (Hopf, 2004).

Data Analysis

Quantitative data were collected using test tools and questionnaires, and recorded in an Excel spreadsheet in a tabular format. The data were analyzed using SPSS version 25. For the test data, descriptive statistics were used to compute the mean and standard deviation for tests administered to both students who studied using the jigsaw method and those who used a lecture-based approach. Inferential statistics were also computed.

Data from the questionnaires, which assessed students' views of the jigsaw method and their self-perceived benefits of the method, were analyzed using descriptive analysis methods such as percentages and frequencies. This provided a comprehensive overview of the collected data. Tables with percentages and frequencies were organized into different sections of the results. Responses to open-ended question about challenges faced during the jigsaw intervention were analyzed using interpretive analysis. Qualitative data from interviews were thematically analyzed. These data were recorded in textual form and fully transcribed from audiotapes. The transcripts were divided into segments, which were then coded and categorized into different themes.

Table 1 Independent t-test results for statistical comparison of Jigsaw cooperative learning and lecture-style learning approaches

Learning Approach	Mean Score	Standard Deviation	d	t	p-Value
Jigsaw Cooperative Learning	7.45	0.90	38	8.23	0.001
Lecture-Style Learning	5.12	0.79			

Results

Contribution of jigsaw method to students' performance in biotechnology

At the conclusion of the jigsaw sessions, participants took a test to evaluate their understanding of biotechnology concepts. Descriptive and inferential statistics, including the mean and standard deviation, were computed for the test items related to both the jigsaw and lecture materials, as detailed in Table 1. The analysis revealed that the mean score for the jigsaw cooperative learning approach was **7.45** with a standard deviation of **0.90,** compared to a mean score of **5.12** and a standard deviation of **0.79** for the lecture-based approach. A comparison of the test scores indicated a statistically significant difference in performance between the two methods ($t = 8.23$, $df = 38$, $p < 0.001$), demonstrating a clear advantage for the jigsaw cooperative learning approach.

Students views toward the effectiveness of jigsaw method in learning biotechnology

Table 2 Students' views on the implementation of jigsaw as a method of instruction

Statements	Disagree	Neutral	Agree
1. Using jigsaw method motivated the students to learn	0(0.00%)	2(5.00%)	38(95.00%)
2. The subdivision of the content in small pieces helped me to easily master my part of work	1(2.50%)	3(7.50%)	36(90%)
3. Learning through jigsaw method promoted my autonomy/self-directed learning	2(5.26%)	1(2.63%)	35(92.11%)
4. The use of jigsaw will be useful to the students in future application of knowledge	2(5.13%)	2(5.13%)	35(89.74%)
5. The assignment of task ensured accountability in learning	2(5.13%)	3(7.69%)	34(87.18%)
6. Learning in small group enhanced my understanding	4(10%)	2(5.00%)	34(85%)
7. Teaching and being taught by peers enhanced in-depth knowledge of the topic-	5(12.50%)	1(2.50%)	34(85.00%)
8. This is an effective way of learning to integrate in the curriculum	3(8.33%)	1(2.78%)	32(88.89%)
9. Jigsaw method can enhance the learning skills in slow learners.	4(10.26%)	3(7.69%)	32(82.05%)
10. Jigsaw learning allowed equal participation in discussion during the preparation of the material to present	5(12.50%)	4(10.00%)	32(78.95%)
11. The materials and resources necessary to learn about their topics were available	7(18.42%)	1(2.63%)	30(77.50%)
12. The time provided for preparing and presenting the session was sufficient	15(37.50%)	2(5.00%)	23(57.50%)
13. Through the jigsaw sessions the role of teacher as facilitator was confirmed	13(32.50%)	4(10.00%)	23(57.50%)

For their perception of the effectiveness of the jigsaw method in learning biotechnology, the students were made to rate on a 5-point Likert scale their agreement to statements about their experiences with the jigsaw method. Table 2 presents the results of the students' ratings.

The statement "Using the jigsaw method motivated the students to learn" received approval from the majority of students, 95.00%. This was followed by "The subdivision of the content into small pieces helped me to easily master my part of the work," which was endorsed by 90.00% of students. Additionally, 92.11% of students also agreed that "Learning through the jigsaw method promoted autonomy/self-directed learning", while 89.74% agreed that "The use of the jigsaw method will be useful for students in the future application of knowledge". On other side, 88.89% of the participants agreed that "This is an effective way of learning to integrate in the curriculum". Furthermore, 85.00% of students agreed with the statements "Teaching and being taught by peers enhanced in-depth knowledge of the topic", "The assignment of tasks ensured accountability in learning", and "Learning in small groups enhanced my understanding". 82.05% of participants indicated that "Jigsaw method can enhance the learning skills in slow learners"; 78.95% mentioned that "The materials and resources necessary to learn about their topics were available" while the statement "Jigsaw learning allowed equal participation in discussion during the preparation of the material to present" was highlighted by 77.50%. However, the statements "The time provided for preparing and presenting the session was sufficient" and "Through the jigsaw sessions, the role of the teacher as facilitator was confirmed" had the lowest approval rates, at 57.50%.

The focus group interview also provided some information on how students perceive the application of jigsaw method. Many students talked about the responsibility in learning. For example, one student stated that "*This method makes me responsible. Before, I use to seat and to watch others working on group assignment. In addition, it stimulated my self-directed learning".* Another added" *Yes,*

Table 3 Students' personnel perceived benefits from jigsaw method (N=40)

Noticed benefits of Jigsaw method	Number	Frequency %
1. Improved communication skills	37	92.50%
2. Eagerness to learn	31	77.50%
3. Teamwork/ Solidarity	37	92.50%
4. Acquisition and retention of more knowledge for long time	36	90.00%
5. Sense of belonging/ self esteem	34	85.00%
6. Analytical, critical and problem-solving skills	32	80.00%
7. Fun learning atmosphere	35	87.50%
8. Teaching skills	28	70.00%
9. Learning by using various resources	31	77.50%
10. Confidence	32	80.00%
11. Patience	10	25.00%
12. Friendship	35	87.50%
13. Active involvement	35	87.50%
14. Enhanced performance	37	92.50%

jigsaw is a good method. Even slow learners were also considered which promoted their understating of the subject". Students also agreed that they were motivated to work with a small part of the whole content as it was easier to learn and deepened the knowledge. One said that "*It was not stressful to learn a section of the whole content*". Another argument by saying that it was exciting to learn from their peers. He also added that they were free to ask any question to understand than in normal class where they fear teachers. In addition, they did not stop listening as it was not bored to hear different voices and new things from each member of the group. For instance, a student stated that*" I learned the material much better through discussion with my peers in small group. It promoted my desire to attend the class and sharing ideas. In the previous lessons, you can even meet a lecturer who tells us to keep quiet once you seek clarification from your comrade".*

The students' self-perceived benefits of using jigsaw method in learning biotechnology

The students were asked to point out the benefits they have perceived during the implementation of the jigsaw method. The data analysis revealed that the most frequently cited benefits were improved communication skills, teamwork/solidarity and enhanced performance by 92.50% of participants. This was followed by 90.00% who reported the acquisition and retention of more knowledge for long time. Additionally, 87.50% of participants indicated a fun learning atmosphere, friendships, and active involvement, while 85.00% mentioned a sense of belonging/self esteem. Furthermore, 80.00% of students highlighted confidence, analytical thinking, critical thinking, and problem-solving skills. On other side, teaching skills were highlighted by 70.00% of students while 77.50% pointed out eagerness to learn and learning by using various resources. Patience was mentioned by the smallest percentage, 25.00%, of students. The overall results are shown in Table 3.

Both questionnaire and face to face interview revealed that students have positive views towards the use of jigsaw cooperative learning. They mentioned many benefits of using jigsaw method. Some students confirmed that retaining knowledge for long time helped them to answer easily and with confidence to various asked questions.

This contributed to their performance and will allow them to apply what they learned. They also realized that the value of helping each other to reach the common goal reduced the desire of studying alone by focus more on a competitive spirit. One student commented that "*I agree that jigsaw was an excellent method as it equipped us with various skills such as teamwork and social skills even needed for professional positions".* Another continued and indicated that "E*veryone was actively involved and eager to contribute to the learning process to find out solutions to our task".* Another confirmed that *"I can also add that more interaction created and promoted friendship among us. Now we got know each other, you can talk to someone you would not normally talk to."*In this line, another also reported that "*With this method, we got a chance to socialize and to develop skills to analyze some issues, to criticize them and arrive to solve them together by respecting other people's opinions".* Furthermore, students also liked working with individuals seeing things from various perspectives and through research by using various resources arrive to generate their own learning material instead on relying on the handouts prepared by the lecturer. During interview, students tremendously stated that they really enjoyed a fun learning atmosphere the jigsaw sessions has created and wished that it can be introduced in teaching

approaches normally used to teach biotechnology.

Constraints faced by students during jigsaw sessions of biotechnology

For this part, students were asked an open-ended question to identify the constraints they encountered during jigsaw sessions. The analysis of their responses revealed some constraints, as presented in Table 4. The issues reported include time limitations, insufficient guidance, disturbances during the sessions, a limited access to learning resources, a lack of trust, difficulties in delivering content and poor peers' evaluation.

About the obstacles to the implementation of jigsaw method in learning, students insisted more on time constraint and low guidance. One stated that "*As the time keeper, I had difficulties to manage the given time as the method seems to require much time to meet the goal".* Another exclaimed that" *"It was not easy for one facilitator to find enough time for sufficient guidance to each group or intervene in case of need to ensure the quality of the learning material that was being prepared".* Students also pointed out the problem of English language used as a tool of instruction. For example, one participant stated that "*Some of the performing students were challenged by language skills when teaching their peers. As*

Table 4 Constraints faced by students while learning biotechnology with jigsaw method

S/N	Constraints	Students' experience
1.	Time limitation	• The technique requires some time to give instructions on how jigsaw works and forming groups • The time was short for depth completion of the topic • Some time was required to give more explanation to slow learners • Insufficient time for presentation as 5 experts in each group have to teach their topics
2.	Inability in delivery	• Students were not capable of teaching well because of the language barrier even that they understood
3.	Insufficient guidance	• It was not easy for one teacher to adequately facilitate all groups. • The time spent in each group during facilitation was not enough • The technique requires the teacher to make considerable effort to facilitate students
4.	Disturbance	• Some individuals tended to dominate in expert groups which disturbed the monitoring • They appeared few individuals who not willing to participate and tended to brought things not related to the topic or to asked explanation on completed part of the material.
5.	Access to learning resources	• It was not easy to get access to online resources because of internet connection • There was a lack of enough teaching and learning materials to use in research for the given topic
6.	Lack of trust	• There were worries about the accuracy of our own prepared learning materials • The doubts about the decisions made as students
7.	Poor peers'	

results, the group members gained few things compared to what they should receive". Participants illustrated that the method not only asks good understanding but also requires adequate communication skills. They also revealed that some members showed bad behavior. One student reported that "*It was hard to work with students who are not willing to participate".* Another student intervene by confirming this and said*" Yes, Yes, you find them providing few contributions about the topic and disturbing us by asking explanation about the addressed issues".* Another ending the conversation by urging that, the lack of strong internet connection was a challenge on the application of jigsaw method. He said that" *Jigsaw learning also requires the use of internet to avail additional resources and it was very slow given that the time to prepare the material to teach was also running*".

Discussion

The jigsaw method is considered effective in improving favorable students' learning outcomes including understanding of the subject concepts leading to the improving in the scores (Bengkulu, 2022; Dacosta & Fabella, 2023; Effendi-Hasibuan et al., 2020; Hutapea, 2022; Juweto, 2015; Morgan, 2014; Sahrul et al., 2022; Seyed Bagheri et al., 2018). The results of this study indicated that the students enhanced their understating in the studied material which allowed them to perform better in the test provided after jigsaw sessions compared to a group of students studied through normal way of teaching. The similar results were indicated in study investigating on the effect of the jigsaw-based cooperative learning method on an increase in understanding and student performance (Azmin, 2015). Previous studies also reported the increase in students' performance in biology and in others subjects with the use of jigsaw strategy (Jainal & Shahrill, 2021; Juniawan et al., 2023; M.J. & M., 2021; Seyed Bagheri et al., 2018; Slish, 2005; Suzanti et al., 2023). This suggests that the needed knowledge grasped by learners during jigsaw sessions were not only retained but also understood. This greatly influenced the increase of their score compared to students studied normal way of teaching.

Concerning the perception to respect on its implementation based on its structure, the students were positive about jigsaw method. The use of small group promoted their understanding. Previous studies also reported the impact of learning as a team on comprehension of science concepts (Nusrath et al., 2019). During jigsaw sessions, students also agreed that the deep knowledge was an outcome of being teaching by their peers. It was confirmed that students understand more when they learn from their peers (Gondo & Mbaiwa, 2022). The findings from interview revealed that they feel comfortable with their peers; they can ask any question to understand the materials which is being taught.

In the present study, students approved that subdivision of the content in small manageable pieces and assigning one piece to each student ensured accountability in learning, mastering of the material and group effort to attain a high level of success. In addition, it was easy, more focused, and not stressful to work with a small portion of the whole content for them. In addition, each student was obliged to be responsible to its part, to seek for expertise on it in order to succefully teach it to their peers (Juniawan et al., 2023).

The effective way of discussing was approved in this study by most of the students, as also pointed out in the study by Lie (2005). When discussing in jigsaw sessions, every member takes part to accomplishment the given task. This developed the sense of interdependence among students to achieve favorable learning

outcomes. Participants also indicated that the use of jigsaw was useful to them in future application of knowledge in various situations including making decisions to some issues related to their subject. Nowadays, a range of scientific social issues such as practices related to biotechnology are apparent. It was written that the knowledge acquired through collaborative learning is influential on decision making process (Tekbiyik, 2013). The way jigsaw is structured also helped students to improve their autonomy, motivation, and self-directed learning as also supported by other researchers (Patil & Kumbhar, 2022). The increase in motivation comes from the responsibility of each student has of developing the material to be taught to their group mates which also leads to active learning.

There are skills that students need in order to promote their knowledge and understanding in a particular subject area (Dacosta & Fabella, 2023). In this study, students have self-perceived that the jigsaw paradigm influenced the development of these skills where communication skills and solidarity were selected by high proportion of students (92.50%). The jigsaw has been used as a tool to help students to communicate (Effendi-Hasibuan et al., 2020; Nau & Djalo, 2019; Yozza et al., 2019). Friendship also enhanced among students as also stated in some studies (Costouros, 2020; Rosita & Leonard, 2015). Among the benefits listed, patience was shown at least percentage of 25.00%. This suggested that disturbance was not high.

Students also noticed that their competences to understand the subject concepts, retain information, apply knowledge, analyze and evaluate were developed. Jigsaw approach was used to teach the concepts difficult to understand to retain knowledge for long time and to apply it (Persky & Pollack, 2019; Gömleksi˙z, 2007 and Tran & Lewis, 2012). Jigsaw instruction was confirmed to create Bloom's taxonomy levels including the ability to innovate and evaluation also mentioned as benefits from jigsaw method (Dhage et al., 2016 and Jafariyan et al., 2017)

The results of this research also indicated other learning achievements perceived by students which are critical skills and problem solving skills, creativity, teamwork, critical thinking and teaching skills also resounded in the study by Subiyantari & Muslim (2019) and Thenu et al. (2023). Active involvement and enthusiastic about learning were also mentioned and similar results are found in the study of Hidayah et al., (2017).

The students also benefited from jigsaw pedagogy a fun learning atmosphere. With this pedagogy, students also got the opportunities of using various resources during the preparation of the material to be taught. Jigsaw sessions also boosted self-confidence and sense of belonging among students. In addition, sense of belonging was seen to stimulate students to contribute for the success of the whole group while self-confidence helped to overcome fear and shines as also reported in face to face interview (Costouros, 2020).

Even that many students found the use of jigsaw positive, however, some students expressed their concerns to this approach. The role of the teacher as a facilitator, motivator, and evaluator was shown insufficient. The learning needs of students were not supported in all group as desired as also indicated by Ekasari et al. (2017). This suggests that low guidance may result in generation of the content of low quality. In this context, few students expressed doubt to their own developed learning materials in term of quality, claiming that it may content unneeded information or lack an important one. The same concern also resounded in the study carried out by Costouros (2020). Thus, it is better to encourage the member of the group to trust each other for their success. In addition, students also pointed out the

problem of internet connection while searching for online resources and it was shown that the success of the implementation of teaching methods depends on the availability of instruction materials (Elkhidir, 2020).

The constraints of time resounded in this study, was also indicated as a main weaknesses associated to the jigsaw approach (Effendi-Hasibuan et al., 2020). In particular, time was identified as an obstacle to jigsaw process (Effendi-Hasibuan et al., 2020). Students reported that they did not come to an end of their task or deeply finish the task due to the time limitation (Nusrath et al., 2019; Effendi-Hasibuan et al., 2020). It is better to carefully organize jigsaw process and related activities to use well the given time. It is essential to consider constraints because of its impact on students for a successful jigsaw implementation.

Conclusion and recommendations

This study highlights the significant impact of the jigsaw method on students' understanding and performance, outperforming traditional lecture-based approaches. The results showed a statistically significant improvement in the test scores among students taught using the jigsaw method compared to those who received lecture-based instruction. This method proved effective in enhancing students' test scores and overall learning outcomes. Moreover, the jigsaw method fostered an engaging and enjoyable learning environment. Students reported positive experiences with active and equal involvement in the learning process, which promoted teamwork, effective communication, and deep understanding of the subject matter. The method encouraged students to take responsibility for their learning, leading to greater autonomy, interdependence, and development of essential cognitive competencies such as analytical thinking, creativity, and problem-solving. It also strengthened social skills and collaboration between teachers and students, making the classroom experience more interactive and meaningful.

However, the study also identified challenges in implementing the jigsaw method, including time constraints and low guidance. These obstacles need to be addressed for the method to be more effective. Policymakers, educators, and researchers can use these findings to improve teaching and learning outcomes by incorporating active learning strategies like the jigsaw method. Further research is recommended to explore the application of this approach across different subjects and educational levels to explore its impact and effectiveness.

Limitation

This study investigated on the effectiveness of jigsaw method on university undergraduate students learning biotechnology by focusing on a specific topic. The research can be replicated with different topics in the same course or with different student groups on the same topic to validate the findings. Additionally, increasing the sample size in future studies could help determine whether the results are consistent with other research or reveal new outcomes.

Acknowledgements

The authors are grateful to the Department of Biology of University of Rwanda-College of Science and Technology for its assistance to meet participants. We also thank all students for their active participation and commitment in this study.

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