Ontology-Driven Intelligent Group Pairing in Project-Based Collaborative Learning

Asma Hadyaoui[a] and Lilia Cheniti-Belcadhi[b]
Sousse University, ISITC, PRINCE Research Laboratory, Hammam Sousse, Tunisia

Keywords: Assessment, PBCL, Peer-Group Feedback, Ontology, PAPI Learner, LOM, Intelligent Pairing, Agglomerative Clustering, Critical Thinking, Creativity.

Abstract: In this research project, we investigate the influence of real-time online feedback from peer groups on the assessment of group work in the setting of Project-Based Collaborative Learning (PBCL). Peer feedback plays a crucial role in assisting students in evaluating their learning progress and acquiring valuable skills. Nevertheless, its effectiveness in group environments has yet to be explored. To tackle this issue, we propose an intelligent approach driven by ontologies to collect pertinent peer group feedback from the most compatible groups. We make use of agglomerative clustering to identify groups that closely match and connect them to exchange feedback. We utilize the information embedded in the ontology to create pairs of groups exhibiting similar behaviors and dynamics during project-based learning activities. To assess the effectiveness of our approach, we divide our dataset into two equal parts. We apply our intelligent pairing method to one half and a random approach to the other. We conduct assessments both before and after peer group feedback to measure its impact on project outcomes, including critical thinking and creativity. The results indicate a substantial improvement in project outcomes, particularly in terms of critical thinking and creativity, due to peer group feedback. Additionally, the groups formed using the agglomerative clustering algorithm demonstrate a higher increase in project validation (8.33%) compared to the random approach (5.27%). Our research underscores the effectiveness of integrating intelligence into the peer group feedback process, especially in the context of PBCL. The proposed ontology presents a promising solution for optimizing the assessment process, leading to improved results and the cultivation of critical thinking and creativity among students.

1 INTRODUCTION

Utilizing formative assessment has demonstrated its potential to enhance student engagement and promote knowledge retention. However, it's crucial to acknowledge the existing methodological challenges when it comes to substantiating claims of its effectiveness (Bennett & Service, 2014). Formative feedback holds a pivotal role in the realm of higher education assessment. Hence, it becomes imperative to explore alternative assessment approaches that incorporate and enhance formative feedback. Feedback is widely recognized as a cornerstone of educational practice and a fundamental catalyst for students' development and learning (Clark, 2012). At the heart of the learning process lies feedback, as it provides students with the necessary skills to construct meaning and independently regulate their educational path. This encompassing concept encompasses both structured, formalized feedback and comprehensive feedback, characterized by in-depth, open-ended commentary (Hwang et al., 2023). Peer feedback emerges as a pedagogical practice that empowers students to engage in reciprocal assessment, allowing them to provide and receive constructive insights on their peers' work concerning the same assignment, thereby elevating their academic achievements. Peer-to-peer feedback constitutes an educational approach that proves highly advantageous for students (Topping, 1998). Through this process, students not only enhance their comprehension of learning objectives and success criteria but also cultivate their ability to provide valuable feedback to their peers. Collaborative

[a] https://orcid.org/ 0000-0002-7006-8735
[b] https://orcid.org/ 0000-0001-8142-6457

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learning settings, featuring peer feedback, yield advantages not only for the receiver but also for the giver of feedback. The act of aligning learning objectives and success criteria within another's work provides invaluable learning experiences. This assertion is corroborated by a study (Dong et al., 2023) underscoring the importance of considering students' competencies and attitudes in the dynamics of giving and receiving peer feedback. Furthermore, this research enhances our comprehension of peer feedback literacy and illuminates the complex relationship between feedback literacy and student attributes, as substantiated by the creation of a comprehensive measurement instrument. In a similar vein, another study (Wu & Schunn, 2023) has posited that encouraging students to actively engage in activities that necessitate explanations and revisions in response to feedback can yield significant improvements in their learning outcomes. Over the past few decades, there has been considerable academic interest in peer feedback, with educators advocating for its integration into educational practices. One notable study by (Lin & Lin, 2017) explored the effects of anonymous online peer assessment facilitated through a Facebook application on participants' perspectives regarding learning, fairness, and attitudes. The results indicated that the utilization of online anonymous peer assessment had a favorable effect on participants' attitudes and their perception of the learning experience. However, another study (Banister, 2020) explored the challenges and attitudes associated with peer feedback among undergraduates studying academic and business English. By employing the principles of Exploratory Practice, the authors aimed to understand why students may not value peer feedback. Additionally, in a previous study (Cheniti Belcadhi, 2016), we proposed an intelligent framework for tailored feedback, leveraging Semantic Web technologies. This framework provides individualized feedback for self-assessment and proves valuable in the context of lifelong learning. In a different setting, the study (Chang et al., 2020) gave fifth-grade students a chance to learn about a geological park in a natural science class by using peer review in virtual reality design activities. However, while peer assessment in collaborative learning environments typically involves interactions between individual learners in a group, there is a lack of research addressing peer assessment between groups of learners, where both the assessee and the assessor are groups. Given these considerations, we recommend a reevaluation of the peer group feedback procedures by incorporating real-time feedback mechanisms to foster effective peer-to-peer communication and ensure clear performance assessment. Drawing on a comprehensive review of existing research, our proposal centers on peer feedback within a PBCL context. It presents a conducive environment for students to assess each other's performance, offer scores or grades, and provide constructive written or oral feedback to enhance learning and growth (Hwang et al., 2023). Our investigation will address the following research inquiries: Does peer feedback impact group performance? How can we determine the most suitable peer group for both receiving and providing feedback? Does the selection of peers influence the quality of feedback and, consequently, its effectiveness?To address our research queries, we carried out an investigation involving a cohort of 312 undergraduate students who were enrolled in the initial stage of their degree program within our academic department. The study was conducted during the first semester of the academic year 2022-2023, with students being organized into smaller groups, comprising either 4 or 3 learners. Each group was assigned the same collaboration project. We proposed an intelligent method for generating pairs of groups for them to provide feedback, taking into account their ontological attributes and characteristics. We designed the ontology called PeerGroupOnto, to capture the key concepts and relationships relevant to peer group formation and feedback in the context of PBCL. The proposed ontology leverages semantic web technologies and eLearning standards to ensure data reusability and interoperability. Our proposed intelligent approach relies also on unsupervised machine learning, namely the Agglomerative clustering algorithm as it allows us to construct a tree-like structure from groups of comparable students. We are delighted with the initial grouping since we desire to form couples. As a grouping criterion, we used the similarity of intra-group interactions, which reflects group dynamics. To evaluate our method, we divided our dataset in half and applied our proposed method solely to one half, while the other half was randomly paired. An evaluation is conducted before and following peer group feedback during a chat session. Through synchronous discussions with peers, groups could reevaluate their answers and project success considering the many viewpoints supplied by their peers.

The integration of ontology and the utilization of an intelligent pairing approach based on the agglomerative algorithm have demonstrated significant synergies, leading to more effective and meaningful collaborative learning experiences. The ontology serves as a foundational knowledge representation framework, capturing domain-specific concepts, relationships, and properties relevant to the assessment process. By formalizing these elements, the ontology enables a structured and interconnected learning environment, facilitating the seamless identification and organization of peer groups.

In this paper, we start by delving into the relevant literature surrounding collaborative learning settings. This involves exploring how ontology and semantic web technologies are applied in educational contexts. Our focus then shifts to introducing our proposed ontology in detail. This serves as the basis for modeling collaborative eLearning environments and facilitating the formation of peer groups, as well as the assessment process. The integration of ontology and semantic web technologies in our research strengthens its foundation and contributes to the advancement of collaborative learning practices.

Moving forward, we explain the methodology we used to form peer groups and analyze the impact of peer group feedback on project assessment outcomes. Throughout our study's methodology description, we walk through the steps we followed to arrive at our conclusions. We thoroughly discuss these procedures, draw conclusions, and finally wrap up our investigation.

2 LITERATURE REVIEW

2.1 Collaborative Learning

Collaborative learning is an educational approach that involves the gathering of students to engage in discussions about a subject matter relevant to the course or curriculum, to collectively address a problem associated with the topic or generate a product that is connected to the topic. By employing this approach, students have the opportunity to cultivate proficiencies that are pertinent to the contemporary era, encompassing effective communication, analytical reasoning, sound judgment, effective leadership, and conflict resolution (Kalmar et al., 2022). Numerous studies have been undertaken within this setting. The study (Chorfi et al., 2022) introduced a novel groupware system based on Computer-Supported Collaborative Learning (CSCL) to facilitate PBCL within a computer programming education context. A study conducted by the authors (Mhlongo et al., 2020) revealed that PBCL has a positive influence on students' overall academic performance and skill development, ultimately boosting their self-confidence. PBCL is particularly effective at overcoming barriers to strategic knowledge, such as groupthink and collaboration. Additionally, the approach of a semester-long undertaking makes solving complex problems easier and reduces mental strain (Wang & Hwang, 2017). Also, prior research (Hadyaoui & Cheniti-Belcadhi, 2023) centered on predicting disengagement among learner groups in a PBCL context. We created a Collaborative Assessment Analytics Framework (CAAF) utilizing ontologies and the accumulation of formative assessment data. In another study (Awuor et al., 2022), the researchers investigated the correlation between students' proficiency in teamwork and their level of satisfaction in a synchronous online flipped group project-based course. The study specifically focused on exploring the potential moderating influences of group collective efficacy and flipped learning. In the context of asynchronous Computer-Supported Collaborative Learning (CSCL), a study conducted by (Chen & Du, 2022) identified distinct profiles of regulators by analyzing online indicators of collaborative learners' utilization of individual-oriented and socially shared metacognitive regulation strategies. Furthermore, the researchers examined the correlation between regulation profiles and the post-CSCL conceptual understanding, motivation, and learning self-efficacy of the students. The authors (Aranzabal Maiztegi et al., 2022) presented a methodology for creating well-balanced teams by utilizing Belbin's roles. This approach aims to enhance positive interdependence and individual accountability among team members, ultimately leading to improved team performance within a project-based learning setting. The evaluation of the student's performance has been conducted by assessing the scores obtained throughout the project. A significant performance advantage was observed in the Belbin teams when compared to the self-selected teams. Furthermore, the feedback, experiences, and opinions of the students were gathered and compiled. After the academic term, students who engaged in Belbin teams conveyed a more favorable attendance record, necessitating reduced extracurricular study time, and displaying an elevated level of enthusiasm towards the subject matter. In a previous study (Hadyaoui & Cheniti-Belcadhi, 2022b), an assessment ePortfolio-based recommender system for individualized formative assessment in a collaborative online learning environment was developed. This action was taken to improve student performance. The learner's ePortfolio was linked to the ePortfolios of other learners using the same assessment platform, allowing for the generation of beneficial recommendations. In addition, a separate study (Ismail et al., 2023) investigated the efficacy of the think-pair-share (TPS) cooperative learning technique in enhancing student engagement and performance in number-building activities. According to the findings of the study, TPS cooperative learning considerably enhanced student performance and motivation, while simultaneously fostering creativity, teamwork, active learning, and motivation. To accomplish our research objective, we devote the majority of our research efforts to determining the usefulness of PBCL-based peer group input.

2.2 Semantic Web and Ontology

The emergence of the Semantic Web and the incorporation of ontology have had a profound effect on collaborative eLearning. By facilitating the structured representation and organization of knowledge, ontology-based semantic web technologies play a vital role in collaborative eLearning. Ontology facilitates the construction of interconnected learning environments by formalizing domain-specific concepts, relationships, and properties. The authors (Murillo Zamorano et al., 2019) created an ontology-driven collaborative eLearning platform that effectively organized learning materials, resulting in enhanced learner comprehension and engagement. In the same context, the study (Senthil Kumaran & Latha, 2023) proposed an innovative method for providing adaptive access to digital library learning resources. The method employs an ontology-based multi-attribute collaborative filtration system to enhance the precision and efficacy of predicting and recommending personalized learning resources. Moreover, the Semantic Web makes a substantial contribution to collaborative content discovery in eLearning systems. Through the incorporation of semantic annotations, learning resources become more understandable to both human and machine users. In a previous publication (García-González et al., 2017), a novel educational tool was showcased, employing Semantic Web technologies to enrich lesson materials. Furthermore, an independent research endeavor introduced a content recommender system driven by ontology, to tackle cold-start problems encountered by new users. Within this recommendation model, ontology serves to describe both the attributes of the learner and the characteristics of the learning objects. Moreover, Semantic Web ontology promotes the interoperability and reusability of learning resources across a variety of collaborative eLearning platforms. With standardized metadata representation, educational content can be readily integrated into a variety of learning environments and shared with others. By employing ontologies and eLearning standards, including CMI5 for assessing the assessment path and IEEE PAPI for the learner model, (Hadyaoui & Cheniti-Belcadhi, 2022a) introduced a semantic web approach rooted in semantic web principles. These technologies ensure data reusability and interoperability, ultimately improving the efficiency and effectiveness of the personalized formative assessment system within a collaborative learning environment. In addition, Semantic Web ontology enables personalized learning by leveraging learner profiles and preferences to customize content delivery. By utilizing ontology to capture individual learning objectives and preferences, educators can provide students with content that meets their specific requirements. In (Joy et al., 2021), the research introduced an ontology-driven semantic framework to tackle the pure cold-start problem in content recommenders. The ontology effectively captures domain-specific details related to learners and Learning Objects (LOs). Through SPARQL queries, the semantic model leverages learner parameters, including learning style, knowledge level, and preexisting knowledge, to create natural learner groups based on the learner ontology. In the context of collaborative eLearning, semantic annotations play a crucial role in enhancing contextual collaboration. By enriching learning resources and collaborative interactions with meaningful metadata, semantic annotations offer relevant context and enhance knowledge transfer. Additionally, previous research (Nouira et al., 2018), in which the authors proposed an architecture for assessment analytics that employs semantic web technologies. They concentrated on analyzing the collection of assessment activities, assessment outcomes, and assessment context.

3 THE PEERGROUPONTO DESCRIPTION

At the core of our approach lies the creation of a specialized ontology that we call *PEERGROUPONTO,* specifically designed for PBCL. This ontology will act as a structured representation of the knowledge domain, capturing crucial concepts, relationships, and properties that form the foundation of PBCL and peer group feedback.

To ensure seamless integration with existing eLearning systems and enhance interoperability, our proposed ontology will embrace the widely recognized IEEE Learning Object Metadata (LOM) standard ("IEEE Standard for Learning Object Metadata," 2020). By adopting this standard, we enable effortless exchange of learning resource metadata, enabling educational materials to be discovered and reused across diverse platforms.

The PeerGroupOnto, depicted in Figure 1, constitutes a comprehensive set of essential classes for our intelligent Semantic Web framework. These

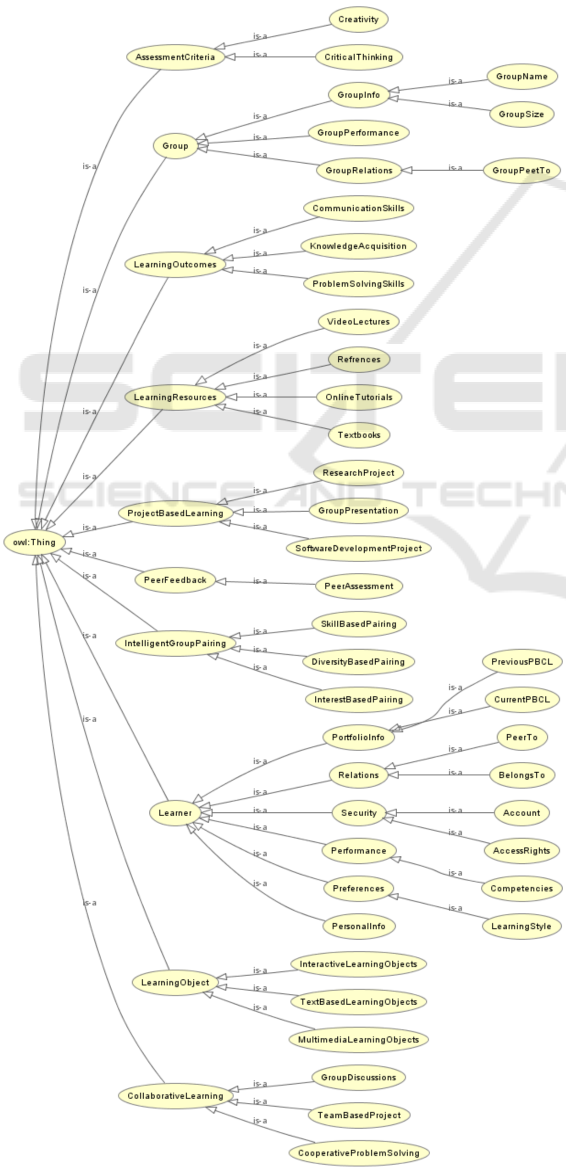


Figure 1: PEERGROUPONTO's classes.

classes include Project-Based Learning, Collaborative Learning, Peer Feedback, Intelligent Group Pairing, Learning Outcomes, Assessment Criteria, Learning Resources, Learners, Instructors, and Educational Organizations. To ensure a seamless implementation of our intelligent pairing peer group feedback system in the PBCL context, each class is enriched with relevant object and data properties, establishing clear connections and attributes. This well-defined ontology structure facilitates effective communication and enables the successful integration of our approach.

In the following, we will describe the essential classes that constitute the ontology, known as the PeerGroupOnto, and their respective properties, which form the foundation of our intelligent Semantic Web framework for peer group feedback in the PBCL context.

Table 1: Learner-related Classes.

Class Name	Description
Learner	Represents and captures various aspects of a learner's profile and characteristics in e-learning.
Performance	Focuses on the learner's academic performance, tracking their progress, achievements, and metrics.
PersonalInfo	Captures the learner's personal information, including name, gender, age, contact details, etc.
PortfolioInfo	Pertains to the learner's portfolio, showcasing work, projects, and achievements to showcase skills.
Preferences	Records the learner's learning styles, interests, and preferences for specific subjects or topics.
Relations	Deals with relationships and connections between learners and other entities within the educational context.
Security	Ensures appropriate security measures and access controls to protect learners' sensitive information.

Table 2: Collaborative learning classes.

Class Name	Description
Project-Based Learning	Represents the learning approach where students collaborate on Python programming projects.
Collaborative Learning	Represents the mode of learning where students work together on shared tasks and projects.
Peer Feedback	Represents the feedback provided by peers in a learning group, supporting evaluation and improvement.
Intelligent Group Pairing	Represents the methodology for forming groups based on factors like student expertise and skills.
Learning Outcomes	Represents the expected knowledge, skills, and competencies students should gain from collaborative learning.
Assessment Criteria	Represents the criteria and rubrics used to evaluate the quality and performance of Python projects.
Learning Resources	Represents educational materials like tutorials and code examples used to support the learning process.
Learners/ Students	Represents individuals participating in project-based collaborative learning.
Learning Object (LOM standard)	Represents a learning resource described using the IEEE LOM standard attributes.

Table 3: Object properties.

Object Property	Description
hasLearningOutcome	Connects a learning activity or project to the intended learning outcomes it aims to achieve.
hasAssessmentCriteria	Links a project or assignment to the criteria used for assessing it.
hasLearningResource	Associates a learning activity with the resources used to support it.
involvesStudent	Relates a project or collaborative learning activity to the participating students/learners.
involvesInstructor	Relates a project or learning activity to the instructors/educators involved.
belongsToInstitution	Connects a learning activity or project to the educational institution it belongs to.
providesPeerFeedback	Links a project or activity to the peer feedback provided by other students.
hasFeedbackCriteria	Associates peer feedback with the criteria used for evaluating it.
isRelatedToLearning Object	Links a learning resource to the corresponding LOM standard attributes for metadata representation.

Table 4: Data properties.

Data Property	Description
feedbackContent	Represents the content or text of the peer feedback provided.
feedbackDate	Represents the date when the feedback was given.
feedbackRating	Represents the rating or score associated with the feedback.
groupSize	Represents the size of the collaborative learning group.
learningObjectTitle	Represents the title of the learning resource described using LOM standard attributes.
learningObjectDescription	Represents the description of the learning resource.
learningObjectKeywords	Represents keywords or tags associated with the learning resource.
learningObjectLanguage	Represents the language in which the learning resource is presented.
learningObjectFormat	Represents the format or media type of the learning resource.
learningObjectLocation	Represents the location or URL where the learning resource can be accessed.
learningObjectTechnicalRequirement	Represents any technical requirements needed to access the learning resource.
learningObjectEducationalLevel	Represents the educational level or target audience for the learning resource.
learningObjectIntendedEndUserRole	Represents the intended end-user role for the learning resource.

4 PEER FEEDBACK EXPERIMENT

Assessment is an essential component of any teaching-learning process. It is the sole method for acquiring a deeper understanding of the learners' knowledge and skills, particularly their creative and critical thinking, in a PBCL setting. In definitions, these terms are occasionally interchangeable. In actuality, they have different conceptualizations because the consequences of human conduct vary. In addition, one of today's requirements is that individuals be able to handle everyday circumstances with both skills (Birgili, 2015). We utilized a 0 to 10 scale to evaluate each learned skill during the duration of the project. As the sum of the two preceding grades, the final grade for the project is based on a scale from 0 to 20. If the final score is 10 or greater, the project will be validated; otherwise, it will be deemed invalid.

Our study involved 312 students enrolled in the transportation and technology engineering first-degree program at our faculty during the first semester of the 2022-2023 academic year. The course, titled "Programming Fundamentals," grouped students into 60 teams of four and 24 teams of three based on their scores. Initially, all groups exhibited varying levels of proficiency in programming. After eight weeks of classes, participants were introduced to the educational content, which encompassed the fundamental concepts of Python programming. Participants worked together to develop a Python application to address a problem. Students designed and coded the application from the ground up, with a focus on problem-solving. In online groups consisting of 3 to 4 members, students engaged in a collaborative process that encompassed brainstorming ideas, analyzing problem statements, and ultimately choosing one problem for their project. The paramount objective was to identify a problem that not only aligned with their educational goals but also fostered meaningful collaboration, critical thinking, and efficient communication. Once the problem was defined, the next step involved categorizing shared and subtasks. These subtasks revolved around various aspects of their Python application, including data processing, algorithm implementation, user interface development, and program logic. The allocation of subtasks was based on the nature of the problem and the intended level of complexity. Collaboratively, the team members assumed responsibility for different subtasks, each focusing on programming their respective portions. To streamline the coordination and integration of code contributions, the group employed Git, which served as a version control system. Throughout this process, the group maintained active communication, sharing ideas, providing feedback, and offering support in coding. Testing and debugging were pivotal phases of the project to ensure its success. Teams rigorously tested their work and addressed any issues that arose. This iterative approach significantly bolstered the software's engineering, functionality, and reliability. The documentation and presentation of the project held great importance. The groups meticulously annotated their code and produced a comprehensive project report. During their presentations, they elucidated the problem statement, outlined their proposed solution, and highlighted the key features of their program. Effective coordination and communication played a vital role throughout the project's lifecycle. The groups utilized online discussion forums, and chat rooms to communicate, share progress reports, seek advice, and offer feedback. This collaborative environment fostered shared learning, the exchange of knowledge, and problem-solving. For all that, we used the online platform Moodle (Modular Object-Oriented Dynamic Learning Environment) (Jan et al., 2018). Throughout the experiment, we provided support and guidance to the students whenever necessary, helping them overcome any obstacles they encountered. The collected data comprised the collaborative project files submitted by the groups, as well as logs documenting the authoring process and the online activity of the forum groups.

Following the experiment, we extensively evaluated the project's achievements and assessed the contributions made in the discussion forum. The primary experiment extended over six weeks in the initial semester, and data from both the achievement projects and forum discussions were subjected to preprocessing for assessment purposes.

4.1 Collaborative Project Assessment

Table 5 provides a means to compare the initial results with the updated findings, focusing on the skills to be acquired through the project's activities.

Table 5: Skills to gain through the project’s activities.

Skills	Approaches	Project’s skills
Critical thinking	Effectively employs logic and reason when relevant to the context.	Development of a Python program to address the proposed issue: ✓ Creation of a list. ✓ Addition of new entries to the listModification of list items. ✓ Sorting the list based on criteria such as Age, Baccalaureate average, and Name.
Creativity	Integrates current information and resources to produce fresh and practical ideas.	✓ Usage of menus to display various program functions. ✓ Utilization of QtDesigner to design visually appealing interfaces.

4.2 Peer Groups Forming

In our experiment, we divided our groups into two sets consisting of 42 groups each, referred to as C1 and C2 in this study. For C1, group partners were randomly paired. In contrast, for C2, we employed an unsupervised machine learning approach called Hierarchical Agglomerative Clustering (HAC). It is widely recognized as one of the most popular algorithms in unsupervised learning (Ben-david, 2014). The first step of HAC involves separating each group of learners into individual clusters, resulting in an initial number of clusters equal to the total number of groups. Subsequent steps involve merging comparable groups until all cases are grouped into a single cluster. This process generates a dendrogram, which is a tree-like structure representing the relationships between clusters, as illustrated in Figure 2.

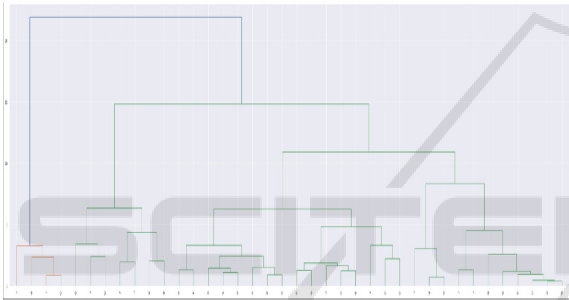


Figure 2: Dendrogram Depicting the Results of Cluster.

Given our objective of creating peer pairs, we stopped at the first step or level of grouping. The success of HAC is heavily influenced by the selection of a suitable linkage criterion, which measures the similarity between two clusters (Ramos et al., 2021). In our approach, we determined that the group's contributions on the forum, reflecting their behavior during the collaborative project, would serve as the linkage criterion. Once the pairs were established, members of each group participated in a chat session, where they presented their work and responded to questions from their peers, reciprocally.

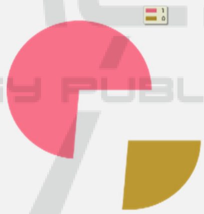
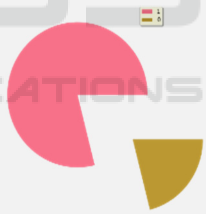
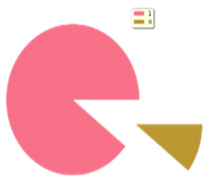
5 RESULTS

This section describes the outcomes of our experiment. We denote by C1 the category of groups whose clustering pairs were produced at random. C2 is our grouping method based on the agglomerative clustering technique depending on the intra-group interactions (Total group contributions on the forum, and the total times online during the project execution). Then, we compare the assessment results of the groups before and following peer group feedback.

5.1 Comparing Project Validation before and after Peer Group Feedback for the Two Paring Groups' Approaches

As demonstrated in *Table 6*, the number of projects that were validated before peer group assessment for the two clustering categories (C1 and C2) has grown after receiving feedback from their peers. Indeed, we notice a rise in the rate of validation (expressed by 1). The results demonstrate an increase of 5.27% in the percentage of project validation from 73.68 to 78.95% for the C1 approach. For method C2, the percentage of validated projects increased by 8.33%, from 81.15 to 89.47%.

Table 6: Comparison of the average of project validation before and after peer group feedback.

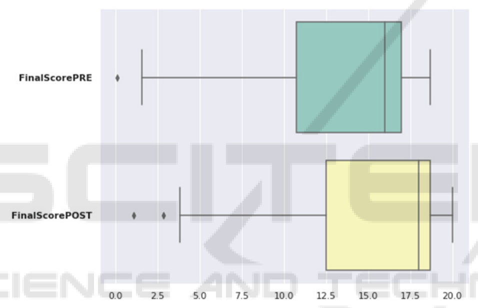
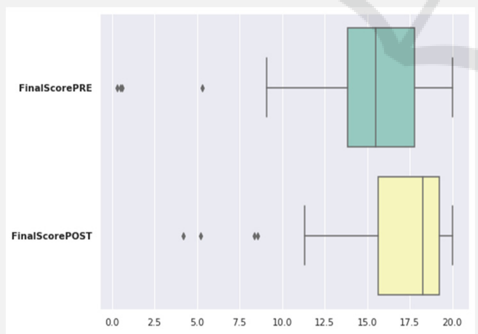
	Project result before peer group feedback	**Project result after peer group feedback**
C1		
C2		

5.2 Comparing Project Learning Skills Outcomes before and after Peer Group Feedback for the Two Paring Groups' Approaches

Following are the outcomes of the group assessments for each of the adopted strategies. According to the subsequent tables, we utilized boxplots to compare the findings acquired before and after peer group feedback. Boxplots are a graphical representation that effectively illustrates the distribution of numerical data and provides insights into the presence of skewness. This is achieved by displaying the quartiles and the mean of the data. Boxplots display the five-number summary, which encompasses the minimum, maximum, first quartile, third quartile, and median values, of a given dataset.

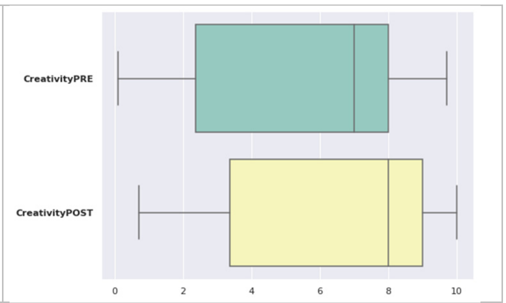
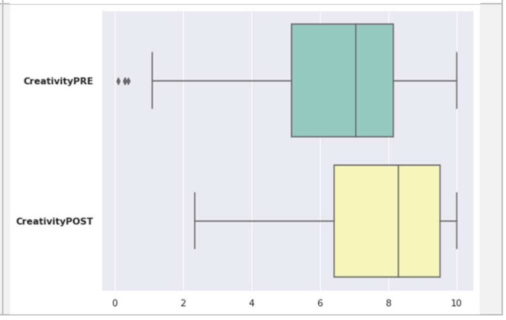
- **Projects' final score before and after peer group feedback**: As shown in *Table 7*, for the initial method C1, 75% of the scores fall below the upper quartile value 17. Thus, 25% of data are above this value. However, after peer group feedback, 25% of data are above 18.25 (a 1.25-point increase). For the second approach C2, 75% of the scores fall below the upper quartile value of 17.75. However, after peer group feedback, 25% of data are above 19 (a 1.25-point increase).

Table 7: Comparing the project's final score.

C1	
C2	

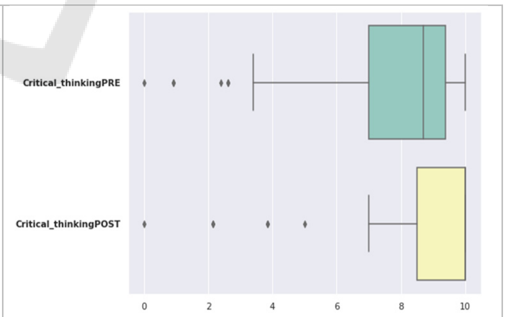
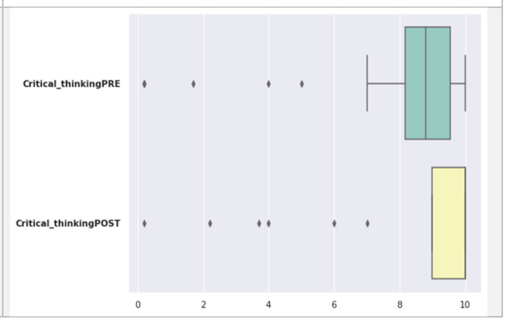
- **Projects' creativity outcome before and after peer group feedback**: By table 8, for the initial method C1, half the scores are greater than 7 and a half are less. After the peer group feedback, this value rose to 8 (a 1-point increase). For the C2 approach, half the scores are greater than 7 and half are less. After the peer group feedback, this value rose to 8.25 (a 1.25-point increase).

Table 8: Comparing project Creativity results.

C1	
C2	

- **Projects' critical thinking outcome before and after peer group feedback**: As seen in Table 9, for the initial method C1, 25% of scores fall below the lower quartile value which is 7. However, after peer group feedback, 25% of scores fall below 8.25 (a 1.25-point increase). For the second approach C2, 25% of scores fall below the lower quartile value which is 7. However, after peer group feedback, this value rose to 9 (a 2-point increase).

Table 9: Comparing project Critical thinking results.

C1	
C2	

6 DISCUSSION & CONCLUSION

The objective of this research was to examine the impact of peer group feedback on assessment outcomes within a PBCL context. Our research strongly advocates for the implementation of peer assessment within the PBCL context, leveraging Ontology and the eLearning standards to optimize the learning experience. Specifically, we relied on the LOM eLearning standard to describe and annotate learning resources, ensuring data reusability and interoperability. Additionally, we employed the PAPI LEARNER model to capture learners' performance, personal information, portfolio details, preferences, relations, and security aspects, creating an ontology-driven model that underpinned our investigation. Our approach involved two key components: the formation of group peers and the implementation of feedback mechanisms. To create peer, we utilized an agglomerative clustering algorithm that considered interactions between group members, aiming to match groups with similar behaviors during the project. This method was applied to half of our learner groups, allowing us to compare its effectiveness with a random pairing approach. The second step involved facilitating real-time feedback through chat rooms, where paired groups could engage in providing and receiving feedback. Comparing the two pairing methods, we discovered that the agglomerative clustering strategy yielded higher skill ratings compared to the random grouping method. Specifically, the results indicated an 8.33% increase in project validation proportions with the agglomerative clustering strategy, compared to a 5.27% increase with the random strategy. In terms of creativity, the random pairing approach resulted in a 1-point increase, whereas the second method yielded a 1.25-point increase. Moreover, the second strategy exhibited a 2-point improvement in critical thinking, surpassing the 1.25-point improvement observed with the random approach. These findings underscore the significance of establishing intelligent pairings to facilitate accurate and valuable feedback. The behavior exhibited by group members emerges as a crucial indicator of group dynamics. Future research endeavors will explore additional criteria against which our results can be benchmarked.

Regardless of the intelligent pairing strategy employed, our findings consistently demonstrated the immense benefits of peer group feedback for the participating groups. The percentages of validated final projects and the overall project scores exhibited notable improvements. These enhancements encompassed various assessed learning skills, including critical thinking and creativity. The efficacy of peer feedback as a formative method for enhancing academic achievement aligns with the findings of previous studies (Mcgrane & Hopfenbeck, 2020). Furthermore, research conducted by authors (Saeedi et al., 2021) has highlighted the positive impact of peer feedback on student motivation, emphasizing its value as an effective teaching technique. Group peer feedback outperforms both no-group feedback and sole instructor assessment. In line with contemporary conceptions of formative assessment, our results strongly advocate for the implementation of peer assessment within a collaborative eLearning environment, particularly when feedback is provided synchronously. However, to further enhance the quality of peer group feedback, our strategy can benefit from integrating additional technologies. For instance, we propose utilizing virtual reality to foster increased interaction and conversation among group pairings. Furthermore, automation of our peer group feedback strategy is a goal we aspire to achieve, incorporating it into the ongoing development of the Intelligent Collaborative Assessment Framework (ICAF).

In summary, our research underscores the significance of peer group feedback in a PBCL setting. It highlights the crucial role of intelligent pairings and synchronous feedback in enhancing learning outcomes. Moving forward, integrating advanced technologies and automation will contribute to further refinement and application of our peer group feedback strategy, within the broader framework of collaborative assessments.

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