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Conflict Resolution in Project-Based Learning

A Mediation Approach

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Abstract

In Project-Based Learning (PBL), the learners collaborate to create projects to adjust and improve their cognitive levels. When learners work on the same project, conflict can arise and may impact their knowledge and relationships, as they often have different skills and backgrounds. This study aims at resolving conflicts among learners within PBL using a mediation approach. The proposed approach involves calculating the similarity between learners to select the proper rescuer based on specific criteria. A set of functions has been used to calculate each criterion. A system called CORE-PBL (For Conflict Resolution in Project-Based Learning) has been implemented to validate the proposed approach. Furthermore, an experimental study had been conducted in the Social Department of Guelma University (Algeria) to address potential conflicts among learners in their projects. The obtained results were satisfactory, as they demonstrated that the cognitive profiles of most students had been improved.

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Introduction and motivation

The integration of Virtual Learning Environments (VLEs) has established a transformative discipline that significantly enhances human learning and knowledge acquisition. This new approach facilitates the learning process for both learners and teachers. This learning model has largely been used during the COVID-19 pandemic, which has disrupted people's global livelihoods since late 2019. Currently, asynchronous learning is utilized to ensure learners' safety at home (Wulandari et al., 2022). Within this context, Project-Based Learning (PBL) has emerged as an effective instructional strategy that encourages students to solve real-world problems, collaborate, and develop creative solutions (Chen et al., 2017). Furthermore, it is carried out through authentic questions and problems within real-world practices (Al-Balushi &Al-Aamri, 2014).

Moreover, PBL implies an approach that serves as a guide for carrying out a project and learning. Helle et al. (2006) identified various reasons to justify the use of PBL. One of these reasons is that each student has a different understanding of the topic and can contribute in different ways.

Learners in PBL environments collaborate to create projects that reflect their knowledge (Bell, 2010). Social interaction involves a struggle over claims to resources, power and status, beliefs, and other preferences and desires. Conflicts can arise among learners in PBL, as they may hold different opinions, perspectives, and contribute varying ideas, or have differing decision-making styles.

In other words, where there are human interactions, there is a likelihood of personal likes and dislikes. These agreements and disagreements among individuals and groups lead to conflict (Crawford & Bodine, 1996; Kapusuzoglu, 2010). The latter is a natural occurrence that can occur in various areas, including business, education, health, and military. Choosing the most appropriate strategy to manage or resolve a conflict depends on several variables, including goals, situational context, interests, and personal skills.

There are numerous benefits to managing conflict resolution, including increased productivity among team members, fostering a deeper understanding of situations, strengthening relationships between users, and developing conflict resolution skills. (Thakore, 2013; Oni-Ojo et al., 2014). For this purpose, we have focused on resolving conflicts among learners in PBL

environments. This resolution positively impacts learners' skills and motivates them to work in groups. There are many ways to resolve or avoid conflict. In this work, the objective is to resolve conflicts through "mediation". The selection of the mediator helps the learners clarify ideas for solving their projects. It is a process designed to improve relationships while resolving specific problems (Oni-Ojo et al., 2014). This mode of conflict resolution is defined as an autonomous approach to resolving interpersonal conflicts (Milburn, 2002). Mediation in education can improve conflict resolution and teacher training, fostering new competencies and enhancing conflict management skills (Yuferova et al., 2021).

For that purpose, we propose a comprehensive method for resolving conflicts among learners in PBL through a peer mediation strategy based on the selection of a learner referred to as the rescuer who intervenes constructively in a dispute. In contrast to previous studies and research, our approach is pedagogically motivated, whereas the rescuer selection criteria are based on educational factors that take into account learners' past interactions, collaborative preferences, and knowledge. A key innovation is that the tool is not just a computational mechanism but a pedagogical aid for supporting collaboration, fairness, and knowledge construction in PBL contexts. The approach is explicitly designed to manage both cognitive and social conflicts, thereby aligning with the collaborative and problem-oriented nature of PBL pedagogy. The selection of the rescuer is based on multiple weighted criteria, including:

- The cognitive profile of the learner (it is calculated using performance on targeted multiple-choice questions aligned with key concepts in the specific domain),
- The social relationship between the rescuer and the conflicting learners (the degree to which a learner interacts with, and prefers to collaborate with, another learner),
- The conflict-of-interest level reflects whether a learner has previously mediated conflicts between the same peers. If the prior resolution was unsuccessful, that learner is added to a blacklist and excluded from a future mediation between those individuals.
- And the history of any successful conflict resolution (whether the learner has previously resolved conflicts effectively).

Several research questions motivated our contribution:

1. How can a conflict between learners in PBL be effectively resolved?
2. How do we identify the relevant rescuer of a problem?
3. How do we identify the nature of the conflict resolution?

To answer these questions, a new approach is proposed to select a rescuer to resolve a conflict between learners by using a set of relevant criteria to identify the most suitable one.

The present work is organized as follows: Section 1 introduces the work. Section 2 deals with some studies related to conflict resolution and PBL. Section 3 describes the structure of the proposed conflict model and the different formulas used for selecting a rescuer. Section 4 presents an example demonstrating how to select the relevant rescuer. Section 5 presents the results of the experiment conducted at an Algerian University, concluding the work and outlining future research directions.

Literature review

Conflict resolution encompasses various areas, including education, business, social sciences, and the medical sector. The literature contains many studies on this topic. This section summarises some works on conflict resolution and Project-Based Learning (PBL).

In PBL environments, learners can create more original projects that enhance their academic results. These projects involve a significant period during which students reflect and improve their knowledge. This reflection can be done individually or in groups (Hanifah, 2022). Research studies have consistently shown that students' skills improve significantly when they apply them in educational settings (Markula & Aksela, 2022).

Zhang and Ma (2023) conducted a meta-analysis of 66 empirical research papers published between 2003 and 2023 on the effects of project-based instruction. They analyse how different moderating variables influence the impact of project-based learning, including subject area, course type, academic period, group size, class size, and experiment duration. They suggested that PBL significantly improves students' learning outcomes compared to traditional teaching models, with a moderate positive effect (SMD = 0.441).

Kortam and his colleagues (2018) studied the influence of PBL on learners' attitudes and motivation. This work is evaluated among biology students, and the authors found that PBL has a positive impact on learners' lives.

To understand how PBL can enhance writing skills and provide valuable insights for educators, Alemneh and Gebrie (2024) employed an experiment on 10th-grade Amharic-speaking students. They compared the effectiveness of PBL with traditional teaching methods and suggested that project-based

learning plays a significant role in improving students' overall and sub-skills in writing.

Within PBL, learners have diverse opinions and levels that can hinder their productivity and impact their interactions and other key performance indicators. Additionally, a lack of knowledge on how to work in a team can lead to conflict between learners, which must be resolved promptly. Project team conflict is a significant obstacle that can hinder the success of inter-firm projects (Von Danwitz, 2018).

There are many definitions of the term "conflict"; each is used according to the application field. For example, in healthcare, Sigut (2013) defined a conflict as "The lack of communication between co-workers, which in turn can be the impetus for medical errors and adverse health outcomes. In conjunction with physical harm, conflict can also cause emotional harm in the form of increased stress on patients, physicians, and managers" (Sigut, 2013). Lists of factors that cause conflicts have been identified through interviews with team members. For example, Chan and Chen (2010) have cited various factors, including poor task management, unfair work allocation, and poor communication.

The phenomena relating to conflicts have been systematically treated by authors in philosophy, biology, sociology, and many other subjects (Abiodun, 2014). For example, in philosophy, Dewey (1998) observed that when obstacles or conflicts interrupt the relationship between human beings and their environment, individuals must use their intelligence to adapt by changing their accustomed modes of thought.

In the context of online education, existing studies addressing conflict resolution problems are relatively underdeveloped compared to the rapid growth of online education (Perry & Pilati, 2011; Schroeder, 2014). Furthermore, resolving such conflicts between students is essential to improving their skills (Payne et al., 2005; Borg et al., 2011; Chan & Chen, 2010). For this purpose, the researchers have conducted various interviews to analyze the causes and solutions that can be implemented to prevent conflict among students. Group conflicts should be addressed because they can lead to destructive behavior and division within the group (Hadad & Reed, 2007). Effective management strategies, including open communication, mediation, and negotiation, facilitate successful conflict resolution in educational settings, resulting in enhanced collaboration, increased student engagement, and a more harmonious environment (Chaudhary, 2023).

In cooperative innovation projects, task conflict indirectly improves success by mediating the effects of tacit and ambiguous knowledge acquired from partners

and knowledge base compatibility (Mu et al., 2021). The following table outlines some related works on PBL. The order of the presented works is chronological.

Authors	Difficulties of the project	Type of the project	Framework/ Project name	Participants
Tiwari et al. (2017)	The difficulty for the students working face to face.	Medicine	N/A	99 students
Aldabbus (2018)	The projects took more than the expected time and students lacked the skills of collaborative work.	Bahraini Primary Schools		24 teachers
Kortam et al. (2018)	Students feel tired when they respond to the questionnaire.	Middle-school biology	N/A	178 students
Alves et al. (2019)	The lack of overall knowledge about the different applications.	Industrial Engineering and Management	N/A	54 students
Santhi et al. (2019)	The system was not developed, and learners are not motivated to work in groups.	English learning	N/A	35 students
Eckardt et al. (2020)	Some students have negative past experiences working in groups	Education	Course EDU 3600	44 students
Alemneh & Gebrie (2024)	Teachers need training and curriculum adaptation to apply PBL in a classroom	Writing abilities of Amharic-speaking	PBL conceptual framework described by Melin et al. (2006)	10 students

Table 1. Summary of difficulties encountered in PBL.

These studies have shown that when the PBL method is implemented, learners improve their knowledge level and evaluate their collective work. In PBL environments, learners develop their attitudes and skills more positively than in traditional learning environments. Most of these studies are evaluated by interviews and questionnaires. The use of this kind of evaluation induces the

learner to answer automatically without reflection. In addition, these works show that learners have different opinions and levels that can lead to decreased productivity, as well as impact their interactions and other key performance indicators. In this situation, the conflict produced between learners must be resolved expeditiously. However, none of these studies took into account the resolution of conflicts in PBL.

The present study highlights the possibility of setting expectations, causes, and consequences before transferring primary responsibility for conflict resolution to learners. Thus, we try to resolve conflicts to produce a better learning experience. Therefore, our work aims to present a new approach to resolving disputes in project-based learning, where learners can serve as conflict rescuers themselves and effectively assist their peers in conflicts.

Our approach differs from those shown in the table above by using formulas and algorithms that take into account various features. The detailed description of the approach is presented in the following sections of the article.

Design of conflict resolution approach in PBL environments

Selecting the rescuer is a crucial task in resolving conflicts between learners. This work suggests a novel approach to resolving potential conflicts between learners with varying profiles and skill sets who need to work together on tasks associated with a shared project. The selection of the appropriate rescuer is guided by specific criteria that take into account cognitive and social features. Once identified, the rescuer can intervene with the learners directly through the system in a digital manner.

At the same time, the teacher plays an important supervisory role by monitoring the process, validating the fairness of the mediation, and ensuring that the conflict is effectively resolved. This ensures that the conflict resolution process remains aligned with the pedagogical objectives of PBL, where collaboration, negotiation, and peer regulation are central learning outcomes.
The main process of our proposition can be summarized as follows:

a. The learning group:

1. The teacher proposes a project for two learners randomly selected from each group. These learners may have different profiles but must work together on this project.

b. Automatic conflict detection:

1. When they encounter a conflict during the project resolving task, they should activate the conflict notification option in the system.
2. Construct the initial conflict model. In this step, they must define its type, causes (reasons), status, etc. (see Table 2).

c. Intelligent selection of a conflict rescuer:

1. Select the relevant rescuers who can resolve this conflict based on some criteria.
2. Sort the rescuers from the previously obtained list.

d. Conflict resolution

1. Select from the list of potential rescuers the first one who can resolve this conflict.
2. Inform the chosen rescuer by sending him a notification to resolve the conflict.
3. Verify if the conflict has been resolved or not.
   3.1. If the conflict has not been resolved, remove this rescuer from potential rescuers and update the base of conflict interests.
   3.2. Repeat from step d.1 with the following rescuer.

e. Updates

- If the conflict is resolved, update the learners' model database and the conflict model database.

Figure 1 below presents the different steps of the proposed approach.

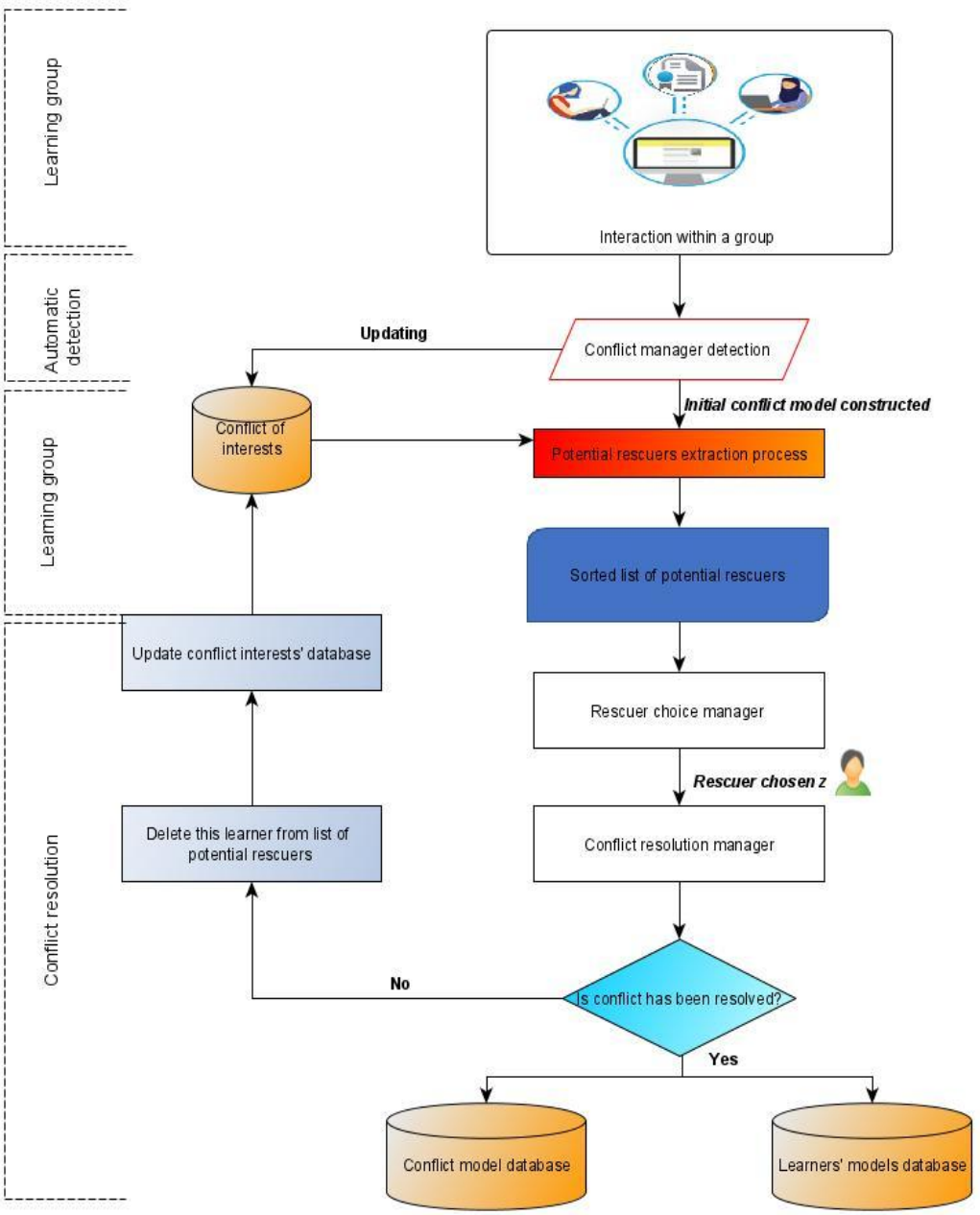

Figure 1. The process of conflict resolution between two learners.

The structure of the proposed conflict model

A conflict exists where there is an interaction between two or more learners with different viewpoints on answering or carrying out a common task. To better understand this conflict, it has to be modeled. To our knowledge, no work has proposed a conflict model. In our proposition, it is defined by its type and causes. In addition, it is characterised by the rescuer and the dedicated time used for resolving it (see Table 2).

As a result, the final conflict model Cf is presented as follows:

$$C_f = \{D, P, T, I, A, D, S, O\} \quad \textbf{(1)}$$

The final conflict model	The initial conflict model	The attribute	The designation
		D : The identifier of the conflict	Presents the identifier of the conflict.
		P : The learners in conflict	Presents a couple of learners (example: (l_1, l_2)) who are in conflict.
		T : The type	The type of conflict: social, technical, etc.
		I: The reasons	Reasons for a conflict: communication, structure, or behavior.
		A : Status	The status of the conflict (Resolved / Not Resolved)
		D : The duration	The duration of a conflict resolution
		S : The rescuer	The rescuer of the conflict
		O : The solution	The solution to the conflict.

Table 2. The description of the conflict model.

The main issue is how to select the relevant rescuer for a conflict. Our vision is presented in the next section.

The selection of the relevant rescuer

In humanitarian action, a peacemaker is "a person who helps in a conflict between two or more individuals on a voluntary basis, without formal authority, by acting impartially and working with one or more parties to resolve the conflict constructively (Radice, 2019)".

Furthermore, according to Nowbahari and Hollis (2010), "a rescuer is a person who helps another individual in a harmful difficult situation".

This rescuer's job is to explore and engage in mediation activities, making an effort to attain peaceful solutions to conflicts.

In our case, to select a relevant rescuer $R(l_z)$ for resolving the conflicts between two learners l_x and l_y, we proposed using four criteria: the cognitive profiles of learners (Mehenaoui et al., 2014), the social relationships of potential partners (Tadjer et al., 2018), the excluded rescuers, and the previous resolution of conflicts (Tadjer et al., 2018; Smith et al., 2002). Then, we calculated the degree of similarity among learners using these criteria. Finally, we established a function to sort the list for recommending the right rescuers according to the learners who needed conflict resolution. Therefore, the rescuer selection was conducted according to the formula outlined in Appendix A.

When the intersection is empty according to the proposed formula (Appendix A), all the learners who have already resolved conflicts are recommended and classified according to their degree of resolution.

Description of criteria for rescuer selection

Similarity concerning the cognitive profile

The learner's cognitive profile (*Cp*) is defined as his level of knowledge according to each learning object, which is assessed through a set of targeted Multiple-Choice Questions (MCQ). In this paper, a learning object is defined as a specific theoretical concept relevant to the course taught (in our case, computer science). A certain number of MCQs (for example, ten) were developed based on the course syllabus and project requirements. To calculate the value of the cognitive profile Cp, we consider the number of proposed questions (n) and the number of correct answers (b_answer), which reflect the understanding of the learner l_z of the specific learning object relevant to the project. The formula used to calculate this profile was validated in our previous work (Mehenaoui et al., 2014; Tadjer et al., 2018) (for more explanation, see Appendix B).

While soft skills such as conflict management and collaboration are important in PBL environments, our model does not directly assess them as learning objects. In this work, learning objects are limited to domain-specific knowledge components. In the selection of a learner l_z , the rescuer of l_x and l_y $learners$ (who are in conflict), the learner l_z must have a cognitive profile higher than that of the learners in conflict l_x and l_y, and also be the most cognitively similar (closest) to them among those with better scores (Mehenaoui et al., 2016) (see Appendix C). Whereas the mediator (or the rescuer in our case) demonstrated high levels of competence in mediation and cognitive flexibility (Gecikli & Yazici, 2026), and he plays a role in cognitive scaffolding (Wood et al., 1976).

Social relationships of the potential partner

The social relationship of the potential partner for a learner refers to how much a learner interacts and prefers to work with his partner. This will later help the

learners to become good conflict rescuers. This factor describes if this partner ($\boldsymbol{l_z}$) is active or inactive with the learner ($\boldsymbol{l_x}$). To calculate this criterion, we have used three activities.

1. The number of views done by the learner $\boldsymbol{l_x}$ on the other learner's profile, noted $\boldsymbol{V(l_x, l_z)}$.
2. The number of communication messages sent by the learner $\boldsymbol{l_x}$ to the other learner, noted $\boldsymbol{M(l_x, l_z)}$.
3. The carried-out communication using the e-mail tool sent by the learner $\boldsymbol{l_x}$ to the other learner, noted $\boldsymbol{E(l_x, l_z)}$.

While these indicators are widely utilized in the literature (Dawson, 2008), we acknowledge that they do not capture the qualitative valence of the exchanges, these metrics serve as an objective proxy for social tie strength, providing a non-intrusive digital footprint of learner engagement that is essential for real-time system recommendations.

To give a final score (see Appendix D), we calculated the average Rel of the previous three scores ($\boldsymbol{V(l_x, l_z)}$, $\boldsymbol{M(l_x, l_z)}$, $\boldsymbol{E(l_x, l_z)}$).

To calculate each action, we have adapted the formula proposed by Tadjer and her colleagues to our problem (Tadjer et al., 2018). For example, to calculate the number of views of a profile, we used the formula found in Appendix E with an example.

Excluded rescuers list

To ensure the long-term effectiveness of the mediation process, the system incorporates a feedback loop based on the success of prior interventions. If the learners $\boldsymbol{l_x}$ or $\boldsymbol{l_y}$ do not prefer the resolution of the learner (rescuer) $\boldsymbol{l_p}$, and they don't want him to resolve another conflict, the next time when there is a conflict between the learner $\boldsymbol{l_x}$ and $\boldsymbol{l_y}$, the learner $\boldsymbol{l_p}$ is added to the excluded rescuers list for those specific learners.

The algorithm used for the detection of excluded rescuers list is presented in Appendix F.

Previous resolution of conflicts

A learner can resolve several conflicts at the same time for different learners. Indeed, to make a final decision on the selection of a learner to solve a problem (i.e. rescuer), we take into account their history of conflict resolution, specifically focusing on previous successful resolutions with the learners involved in the present conflict.

In other words, we look for rescuers who have already solved conflicts r_z with the concerned learners and classify them to assign them based on the degree of effectiveness calculated with the formula found in Appendix G.

The selection of the relevant rescuer

To select the relevant rescuer from a list of learners, we have focused on the above criteria: the potential partner's cognitive profile, social relationship, excluded rescuers, and previous conflict resolution. Based on these criteria, there are qualitative and quantitative values. The quantitative values are the potential partner's cognitive profile, social relationships, and previous conflict resolutions.

We represent each rescuer $\boldsymbol{l_z}$ with three quantitative values (Sim_cp, Rel, dg) in Three-dimensional space(x, y, z) (see Figure 2). This rescuer $\boldsymbol{l_z}$ is the result of his relation between $\boldsymbol{l}_x$ and $\boldsymbol{l}_y$, so we have two different values of the cognitive profile similarity (i.e. $Sim_cp(l_x, l_z)$ and $Sim_cp(l_y, l_z)$), the social relationship of the potential partner (i.e. $Rel(l_x, l_z)$ and $Rel(l_y, l_z)$) and the degree of previous resolution (i.e. $dg(l_x, l_z)$ and $dg(l_y, l_z)$). According to Pythagoras theorem, we obtain the formula found in Appendix H.

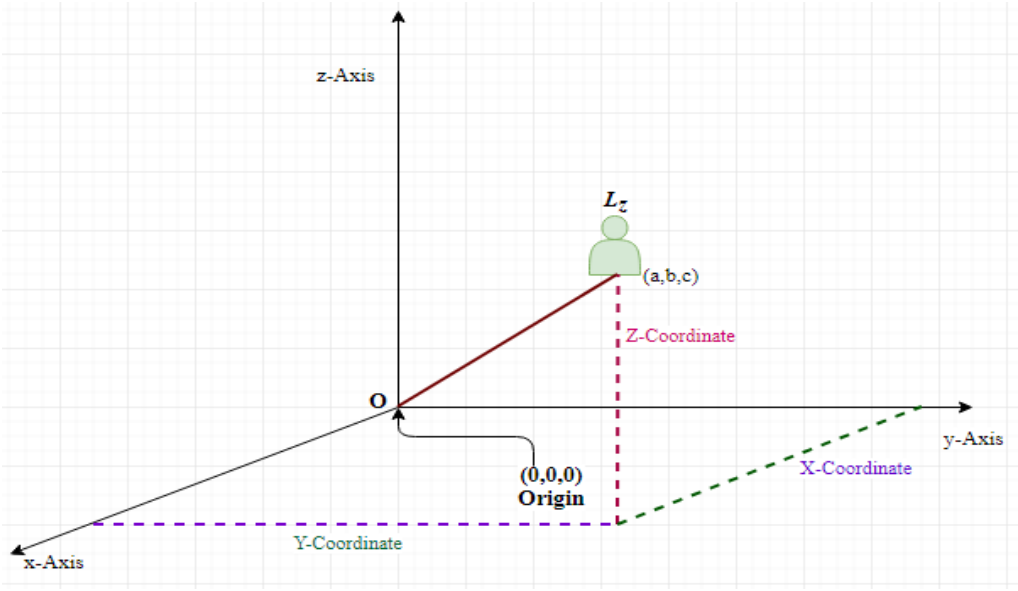

Figure 2. The representation of the rescuer in 3D space.

The above equation is the general form of the distance formula in 3D space. A particular case is when there is no previous resolution of conflict between $\boldsymbol{l}_x$ and $\boldsymbol{l}_y$, so the value of $dg = 0$. In this case, we represent the rescuer $\boldsymbol{l_z}$ in two-dimensional space (2D), and the formula becomes as indicated in Appendix I. A detailed example of recommendation is presented in Appendix J.

Experiment: results and discussion

To validate the idea of conflict resolution, we have tested the prototype utility for sociology students at Guelma University (Algeria). These students can use *CORE-PBL* (For **C**Onflict **R**Esolution in **P**roject-**B**ased **L**earning) at http://www.prdlearn.com/CORE-PBL/ from any internet navigator.

Figure 3 shows an interface from the CORE-PBL system, which presents an example of each learner's project resolution.



Figure 3. Interface from CORE-PBL system.

Participants

A sample of 40 first-year students from the Department of Sociology was selected randomly for the experiment. Students solved projects about Excel software during the period of the experiment. The students were asked to solve some projects, such as calculating the students' average, establishing an invoice, etc. The selected students have been divided into two groups randomly: a control group and an experimental group, with 20 students in each one. *CORE-PBL* environment offers all the necessary resources and communication tools that allow learners to collaborate on a given project.

Methodology

The experiment was conducted (before-after situation) with the students who were selected randomly. As mentioned previously, these students were divided into two groups using a random assignment process without any prior selection criteria (such as gender or academic level). The 'control group' worked without the system (in other words, they don't use the feature of conflict resolution proposed by our system CORE-PBL), while the 'experimental group', worked with the suggested system (with all its proposed features, especially conflict resolution approach). During the project work, some conflicts naturally

emerged among learners due to differences in opinions, task distribution, or understanding of the project requirements. In the experimental group, students used the system to identify a suitable rescuer based on the proposed criteria.

After that, to see the effect of the proposed approach, we compared the results of the experimental group members to those of the group that did not use the developed system (i.e., the control group).

During the experimental period, the students learned to use the Excel software. Then, two members in each group were assigned to resolve a joint Excel software project. Two questionnaires were proposed by the teacher:

- Pre-test Questionnaire: In the first phase, this tool evaluated the initial cognitive profiles and Excel proficiency of all learners to ensure baseline comparability between the two groups.
- Post-test Questionnaire: In the second stage, this questionnaire measured the perceived usefulness of the rescuer recommended by the system. It specifically tested whether the intervention positively influenced the learners' cognitive performance.

In this system, the learners could visualize their cognitive and behavior profiles. In addition, they could interact with each other using different tools (shared space, instant messaging, etc.).

Results and Discussion

To validate our contributions, we proposed to verify the following hypothesis: The null hypothesis is:

> H0: Using the proposed approach does not improve the cognitive profiles of the learners.

The research hypothesis is:

> H1: Using the proposed approach helps learners improve their cognitive profiles.

To verify these hypotheses, we used XLSTAT, which is the leading data analysis and statistical solution for Microsoft Excel.

Before using the t-test, we had to ensure the data was normally distributed. To do this, we used the Shapiro-Wilk test. The obtained results showed that the data was distributed normally because the P-value was greater than the chosen alpha level (α=0.05) for the two groups. Then, the null hypothesis that the data came from a normally distributed population could not be rejected. These results are expressed in Table 7.

Experimental group		Control group	
W	P-value	W	P-value
0,963	0,399	0,920	0,198

Table 7. Test for normality – Shapiro-Wilk.

To verify our hypothesis, we calculated the difference in the students' cognitive profiles. For that, we used a paired unilateral t-test because the sample size was less than 30. The results obtained are presented in Table 8.

The results showed a significant difference between the experimental group mean (Mean=0.350; SD=0,233) and the control group (Mean=0.210; SD=0. 171). A paired unilateral t-test was conducted to assess the progression of each group. The cognitive level of the experimental group improved significantly (t(19)= 6.054; P-value < 0,.0001), while the cognitive level of the control group did not improve significantly (t(19)= 5.480; P-value= 0.102). Therefore, the null hypothesis H0 is rejected. So, the alternative hypothesis is proved, and it demonstrates that selecting rescuer learners based on their profiles significantly enhances knowledge acquisition within PBL environments. Based on the experimental group, the cognitive profile indicates that peer mediation effectively resolves learning conflicts.

	N	df	Mean	SD	tscore	P-value
Experimental group	20	19	0.350	0.233	6.054	$1.23.10^{-8}$
Control group	20	19	0.210	0.171	5.480	0.102

Table 8. Results of experimentation with the t-test.

Conclusion and future work

In education, conflict resolution between group members involves channeling the expertise, energies, and resources of the conflicting groups to find solutions to their common problems. In our context, common projects include accommodating each other's needs, compromising, or working together toward a shared goal in PBL. Therefore, this strategy of learning improves creativity and teamwork competencies.

This paper proposes an approach for resolving conflicts that may arise between learners when they collaborate on a common project. To respond to the first main question, resolving conflict in PBL is crucial. It is essential to select a learner who can help their teammates solve problems within a circle of trust.

To do this, all data about the learners involved in the conflict and their previous conflicts (if they exist) are used. To validate this contribution, the proposed approach was implemented using a system called Conflict Resolution in Project-Based Learning (CORE-PBL), which incorporates various tools. This proposition can be adapted to resolve conflicts in another research.

In response to the questions asked in the introduction section, to effectively resolve a conflict between learners in PBL, it is crucial to know who the most skilled mediator will be to redress the situation. This method will reduce the need to avoid, compete with, or attempt to defeat the opponent. To achieve this, we propose selecting a rescuer from the list of learners who have already successfully resolved conflicts. To identify him, we have used a set of relevant criteria and a set of functions. These are mentioned in the second part of this paper. Regarding the question of identifying the nature of the conflict, we proposed a model that can accommodate various types of projects and have applied it to several domains beyond education. The answer is presented in the last part of this paper.

The experimental results confirmed that the proposed approach enhances learners' cognitive profiles. Furthermore, they demonstrated its effectiveness in promoting knowledge acquisition and conflict management. While the results are promising, this study has some limitations. The cognitive profile assessment was exclusively composed of multiple-choice questions; it may not have provided a comprehensive measure of the deeper or applied knowledge acquired by learners. Another significant limitation of this work concerns the assessment of social relationships. Our three quantitative indicators do not take into account the semantic content of the exchanged messages. Consequently, a high volume of interactions characterized by a negative qualitative valence could indicate that the relationships are not as good as expected, so the mediator could not be the best rescuer or cannot deal with effective mediation.

For future work, the objective is to propose a measure of the amount of conflict between two in-group specific members and how to handle conflict between in-group members and out-group members. In other words, the diagnosis of intragroup conflict should indicate the gravity of the conflict compared to the out-group members. Gravity is defined by the extent of conflict, whether it is too little, too much, or moderate, and how efficiently group members can handle it. Consequently, we propose extending the model to directly address complex multi-learner dynamics. In this case, we deal with multi-learner scenarios by decomposing group tensions into pairwise conflicts, and we acknowledge the need for a more holistic approach. In addition, another future research is to study case-based conflict resolution, which can facilitate the resolution process.

Data Availability

Data generation is available at: https://github.com/Bendjebar/CORE-PBL.git

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Appendix

Appendix A

$$\boldsymbol{Rescuer}\ (\boldsymbol{l_x}, \boldsymbol{l_y}) = \begin{cases} = [\left(list_{sim_{cp(l_x)}} \cup list_{sim_{cp(l_y)}}\right) \cap \left(list_{rel(l_x)} \cup list_{rel(l_y)}\right)] - [list_conf_interest(l_x) \cup \\ list_conf_interst(l_y)] \cup \left[list_{Rs(l_x)} \cap list_{Rs(l_y)}\right] \textbf{ If there was a conflict between } \boldsymbol{l_x} \textbf{and } \boldsymbol{l_y} \\ = \left[\left(list_{sim_{cp(l_x)}} \cup list_{sim_{cp(l_y)}}\right) \cap \left(list_{rel(l_x)} \cup list_{rel(l_y)}\right)\right] - [list_conf_interst(l_x) \cup \\ list_conf_interst(l_y)] \textbf{ Otherwise} \end{cases} \quad (2)$$

Such as:

- $\boldsymbol{Rescuer}\ (\boldsymbol{l_x}, \boldsymbol{l_y})$: List of the learners who can be a rescuer of the conflict,
- $\boldsymbol{list_{sim_{cp(l_x)}}}$ And $\boldsymbol{list_{sim_{cp(l_y)}}}$: List of learners who have a similar cognitive profile as l_x and l_y,
- $\boldsymbol{list_{rel(l_x)}}$ And $\boldsymbol{list_{rel(l_y)}}$: List of the learners who have a social relationship with the potential partner with l_x and l_y,
- $\boldsymbol{list_conf_interst(l_x)}$ And $\boldsymbol{list_conf_interst(l_y)}$: List of the learners who had already resolved conflicts for l_x and l_y (respectively), but these latter don't desire these learners to solve another conflict,
- $\boldsymbol{list_{Rs(l_x)}}$ and $\boldsymbol{list_{Rs(l_y)}}$: List of the learners who had already resolved a conflict between l_x and l_y.

Appendix B

$$Cp\ (\boldsymbol{l_z}) = \frac{\sum_{i=1}^{n} b_answer_i}{\sum_{i=1}^{n} Q_i} \quad (3)$$

Appendix C

$$Sim_Cp(l_x, l_z) = 1 - (Cp(l_z) - Cp(l_x)) \quad (4)$$

All the similarities $sim_cp(l_x, l_z)$ are numbered in [0,1]. Furthermore, If $Cp(l_z) < Cp(l_x)$ then $Sim_Cp(l_x, l_z) = 0$

We apply this formula to all the learners. Then, we order them according to the obtained results.

$$list_{sim_{cp(l_x)}} = \{l_z, l_w, \dots, l_i\}\ i\ is\ the\ number\ of\ learners\ who\ are\ similar\ to\ l_x \quad (5)$$

Example:

For example, the cognitive profile of the learner l_x is: $Cp(l_x) = 0.4$.
If there are ten questions (n=10) and a learner (l_z) has answered six questions (b_answer=6); in this case $Cp\ (\boldsymbol{l_z}) = 0.6$.
So, the similarity between the two profiles is: $Sim_Cp(l_x, l_z) = 0.8$

Appendix D

$$Rel(l_x, l_z) = \frac{V(l_x, l_z) + M(l_x, l_z) + E(l_x, l_z)}{3} \quad (6)$$

Appendix E

$$V(l_x, l_z) = \frac{number\ of\ view\ l_x\ of\ l_y}{Total\ number\ of\ view\ l_x\ for\ all\ learners\ profiles} \quad (7)$$

Example:

For example, we suppose that there are eight learners in the system, and we want to extract the potential partner of the first learner l_1 by using the previous formulas. Table 3 presents the obtained results.

Learner	The views	The messages	The emails	The potential partner
l_1	$l_3 = 4$ $l_6 = 2$ $l_8 = 2$	$l_3 = 1$ $l_4 = 2$ $l_6 = 1$	$l_3 = 1$ $l_6 = 2$ $l_7 = 5$	$l_3 = 0.291$ $l_4 = 0.166$ $l_6 = 0.25$ $l_8 = 0.083$ $l_7 = 0.208$
Number of total actions	8	4	8	

Table 3. Example of the extraction of the potential partner.

According to this table, the learner l_3 is the potential partner of the learner l_1.

Appendix F

Algorithm extract excluded rescuers *(x: learner)*

Input: L: a set of learners

Output: IR(x): a set of irrelevant rescuers

Begin

For each learner **l∈L** and **l <> x** do

If x does not prefer the resolution of **l then**

Example:

A learner l_1 is in conflict with another learner, and we select the learner l_4 to resolve his conflict; if l_1 does not accept any relationship with the learner l_4 then this latter will belong to the list of irrelevant rescuers.

Appendix G

$$dg(l_x, r_z) = \frac{\sum_{i=1}^{k} W_{ri}}{\sum_{j=1}^{k} W_j} \qquad (8)$$

Where:

W_{ri} : the weighting of the conflict resolved by the rescuer r_z,

W_j : the weights assigned for each conflict has been resolved,

k : is the total number of resolved conflicts.

Example:

The learner l_1 has already encountered three different conflicts, and three different learners have resolved them. By using the previous formulas, we obtain the results mentioned in the Table 4:

The previous rescuer	The weighting of the conflict resolution	The degree of conflict resolution
r_3 r_4 r_5	$W_{r3} = 1$ $W_{r4} = 3$ $W_{r5} = 2$	$dg(l_1, r_3) = 0.16$ $dg(l_1, r_4) = 0.5$ $dg(l_1, r_5) = 0.33$
Number total of weights	6	

Table 4. Example of the extraction of the previous rescuers.

Appendix H

$$Dist\ Ol_z = \sqrt{\left(Sim_{cp(l_x,l_z)} - Sim_{cp(l_y,l_z)}\right)^2 + \left(Rel(l_x,l_z) - Rel(l_y,l_z)\right)^2 + \left(dg(l_x,l_z) - dg(l_y,l_z)\right)^2} \quad (9)$$

		x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Sim_Cp	x_1	X	0	0,57	0,76	0,25	0,83	0,64	0,34	0	0
	x_2	0,12	X	0,75	0,35	0,72	0,53	0,87	0	0,95	0
	x_3	0,67	0,13	X	0,41	0	0	0,82	0,97	0,76	0,34
	x_4	0,72	0,83	0,17	X	0,56	0,89	0	0	0,55	0,68
	x_5	0,5	0,25	0	0,53	X	0,95	0,68	0,87	0,19	0,72
	x_6	0,85	0,78	0	0,83	0,35	X	0,57	0,41	0	0,88
	x_7	0,75	0,45	0,17	0,67	0,76	0,22	X	0,12	0,43	0,83
	x_8	0,15	0	0,55	0	0,38	0,72	0,68	X	0,38	0,64
	x_9	0	0,25	0,73	0	0,85	0	0,25	0,56	X	0,15
	x_{10}	0	0	0,27	0,93	0,5	0,45	0,12	0,87	0,34	X
Rel	x_1	X	0,75	0	0,95	0	0,34	0,78	0,5	0,93	0
	x_2	0,41	X	0,56	0	0,19	0,75	0	0,68	0	0
	x_3	0,76	0	X	0	0	0,93	0	0,72	0	0,67
	x_4	0,97	0,5	0,64	X	0	0	0,88	0	0	0,25
	x_5	0,88	0,23	0,35	0,74	X	0	0	0,93	0	0
	x_6	0,95	0,15	0,85	0,5	0,67	X	0	0	0,38	0
	x_7	0,38	0,72	0	0,19	0,87	0,76	X	0,74	0,82	0,76
	x_8	0	0,87	0,39	0	0,56	0,45	0,23	X	0,78	0,95
	x_9	0,25	0,68	0,82	0,36	0,75	0	0,88	0	X	0,35
	x_{10}	0	0	0	0,22	0,48	0,64	0	0,35	0,25	X
dg	x_1	X	0,12	0,5	0	0	0	0	0	0,41	0,5
	x_2	0	X	0,87	0	0,38	0,56	0,25	0	0	0
	x_3	0,41	0,5	X	0	0	0,25	0,75	0	0	0
	x_4	0	0	0,25	X	0	0,72	0,95	0	0	0,75
	x_5	0,5	0,25	0		X	0	0	0	0, 25	0
	x_6	0,5	0,83	0,95		0, 25	X	0	0, 35	0	0, 75
	x_7	0	0	0,15	0	0	0,65	X	0	0	0
	x_8	0,25	0,95	0,75	0,19	0	0,5	0	X	0	0,5
	x_9	0,87	0,67	0	0,25	0	0,75	0	0	X	0
	x_{10}	0	0,25	0	0	0	0,88	0,95	0	0,5	X

Table 5. An explaining example of the proposed approach.

Appendix I

$$Dist\ Ol_z = \sqrt{\left(Sim_{cp(l_x,l_z)} - Sim_{cp(l_y,l_z)}\right)^2 + \left(Rel(l_x,l_z) - Rel(l_y,l_z)\right)^2}$$

Appendix J

EXAMPLE OF RECOMMENDING RELEVANT RESCUER

The following table shows an example of ten learners to whom the proposed approach is applied. We extract the similarity between the learner $\boldsymbol{x_i}$ and the other learners in the system.

N.B. In the last parameter, we identify the learners in the same conflict with the same color. For example, the learner $x_{\uparrow 1}$ solves the conflict between x_2 and x_3 (blue color).

In this example, we try to find the rescuer to resolve a conflict between x_1 and x_2. Using the general formula (2), firstly, we extract the list of the learners who are similar to the cognitive profile($list_sim_{cp}$) of x_1 and x_2, and the values of this similarity.

$list_{sim_{cp(x_1)}} \cup list_{sim_{cp(x_2)}} = \{x_3, x_4, x_5, x_6, x_7, x_8\} \cup \{x_3, x_4, x_5, x_6, x_7, x_9\} = \{x_3, x_4, x_5, x_6, x_7, x_8, x_9\}$

The same goes for the potential partners($list_rel$) of x_1 and x_2.

$list_{rel(x_1)} \cup list_{rel(x_2)} = \{x_3, x_4, x_5, x_6, x_7, x_9\} \cup \{x_4, x_5, x_7, x_8, x_9\} = \{x_3, x_4, x_5, x_6, x_7, x_8, x_9\}$

Secondly, we extract the list of learners who had already resolved conflicts between x_1 and x_2.

$list_{Rs(x_1)} \cap list_{Rs(x_2)} = \{x_3, x_5, x_6, x_8, x_9\} \cap \{x_3, x_5, x_6, x_8, x_9, x_{10}\}$
$= \{x_3, x_5, x_6, x_8, x_9\}$

Thirdly, we extract the list excluded rescuers (see Table 6).

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
list_conf_interst	x_3, x_7, x_{10}	x_8, x_{10}	x_2, x_6, x_8	**X**	x_7, x_{10}	x_3, x_7,	x_5	**X**	x_3, x_8,	x_6, x_8

Table 6. The results of excluded rescuers.

According to the above table, we extract $list_{conf_{interst}}$ of x_1 and x_2, we obtain:
$list_conf_interest(x_1) \cup list_conf_interest(x_2) = \{x_3, x_7, x_8, x_{10}\}$
$list_{Rs(x_1)} \cap list_{Rs(x_2)} = \{x_3, x_5, x_6, x_8, x_9\}$

As a result to the general formula (2), we obtain this list:
$Rescuer\ (x_1, x_2) =$
$[\{x_3, x_4, x_5, x_6, x_7, x_8, x_9\} \cap \{x_3, x_4, x_5, x_6, x_7, x_8, x_9\}] - \{x_3, x_7, x_8, x_{10}\} \cap \{x_3, x_5, x_6, x_8, x_9\}$
$= \{x_5, x_6, x_9\}$

Finally, we classify the learners according to the formula (9)

$$Dist\ Ox_5 = \sqrt{\left(Sim_{cp(x_1,x_5)} - Sim_{cp(x_2,x_5)}\right)^2 + \left(Rel(x_1,x_5) - Rel(x_2,x_5)\right)^2 + \left(dg(x_1,x_5) - dg(x_2,x_5)\right)^2}$$
$$= \sqrt{(0{,}5 - 0{,}25)^2 + (0{,}88 - 0{,}23)^2 + (0{,}5 - 0{,}25)^2} = 0{,}739$$

The same way for x_6, x_9
$Dist\ Ox_6 = 0{,}868$
$Dist\ Ox_9 = 0{,}536$

According to these results, we recommend the first rescuer, who is the learner x_6.