EduColl: A Collaborative Design Approach Based on Conflict Resolution for the Assessment of Learning Resources

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Abstract: To meet expectation for education in the 21st century established by OECD, educational system are grappling with many challenges at different levels. As accrediting bodies consistently ask for evidence of the quality of educational programs, the alignment of learning materials with specific course or program curricula, as well as broader educational standards and guidelines, becomes imperative. This requirement places an overwhelming burden on educational systems, necessitating iterative evaluations from diverse perspectives. Given the involvement of several multidisciplinary stakeholders, conflicts may naturally arise in this intricate evaluation process. To address this complexity, we propose, in this paper, a collaborative design of criteria-based framework approach to evaluate learning materials. The approach allows for a flexible selection process of criteria without predefined order, and it incorporates an automatic conflict resolution mechanism based on user preferences. Our objective is to streamline the evaluation process, enhance collaboration among stakeholders, and contribute to the overall improvement of educational materials in alignment with contemporary educational standards.

1 INTRODUCTION

Building strong education systems is fundamental to development and growth. Providing access to quality education not only fulfills a basic human right, but also serves as a strategic development investment. At the individual level, while a diploma may open doors to employment, it is her or his skills that determine his or her productivity and ability to adapt to new technologies and opportunities (Rogers and Demas, 2013).

At the strategic level, for education systems to deliver quality education, they need to be able to promote both schooling and learning by designing and adapting learning materials to anticipate learners' needs and contexts (Gottipati and Shankararaman, 2018).

Textbooks, learning materials and activities play a significant role in shaping the learning experience of students, and their quality can have a direct impact on the effectiveness of instruction(Morgan et al., 2013).

The ongoing evaluation of them contributes to the continuous improvement of educational practices and ensures that educational institutions and programs maintain high standards (Gottipati and Shankararaman, 2018). It fosters a culture of reflection and adaptability in response to evolving educational needs, contexts and high standards.

For reasons cited above, as the evaluation of learning activities is a multifaceted process, great effort has been devoted to propose criteria and frameworks that ensure a systematic, fair and comprehensive assessment of learning activities, ultimately contributing to the improvement of educational quality and effectiveness (McDonald and McDonald, 1999).

Several meetings and exchanges among multidisciplinary practitioners are organized to collaboratively design, redesign, and adapt such a multifaceted framework (Grover et al., 2014) (Dewan, 2022). This undertaking may become challenging and seems overwhelming given the existence of different perspectives and conflicting situations may emerge. Thus, educational systems, although their interest in improving programs and their willing to embrace the evaluation process, are sometimes discouraged in the perception that any meaningful assessment will likely require unreasonable amounts of time and effort (Dewan, 2022).

To address this complexity, we propose in this paper a collaborative design of a criteria-based framework to evaluate learning materials, called "EduColl", that relies on free-order criteria selection process, where stakeholders freely select their analysis criteria

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or metrics toward competencies and learning activities without being constrained by the selected metrics made by the other ones.

Our main objective is to offer an approach with supporting tools that enhance the collaborative design for a consensus framework of learning materials assessment. This consensus framework, which is elaborated on the basis of the existing grid and the opinions of experts, will likely take into account the specificity of the educational system.

This paper is structured as follows. Section 2 gives an overview of learning materials assessment related work and discuss challenges of collaborative design. Section 3 presents the knowledge about conflict within collaborative configuration, feature models, and minimal correction subsets (MCSs). The proposed approach is explained in section 4. We present an illustrative example and the supporting tool in section 5 before concluding in section 6 .

2 RELATED WORK

A number of studies and frameworks focus on an analysis strategy of learning materials. For example, Baker (Baker, 2003) has developed a framework for the design and evaluation of Internet-based distance learning courses. Morgan (Morgan et al., 2013), also, proposed a systematic tool for assessing learning materials in various dimensions. Bundsgaard et al. (Bundsgaard and Hansen, 2011) introduced a holistic framework to evaluate learning materials and learning design. Leacook and Nesbit (Leacock and Nesbit, 2007) have contributed to this domain with the development of the LORI (Learning Object Review Instrument) framework. LORI allows educators to create reviews that include ratings and comments on nine dimensions: content quality, alignment of learning goals, feedback and adaptation, motivation, presentation design, usability of the interaction, accessibility, reusability, and compliance with standards. Other research focuses on curriculum assessment such as (Vivian and Falkner, 2018) and (Grover et al., 2014).

However, the main focus of the studied research and others is to advance criteria, dimensions, and framework for assessing learning materials. They do not provide any information about how these frameworks are designed.

On the other hand, Kalle et al. (Piirainen et al., 2009) assert that collaborative design not only forms the foundation for developing guidelines to achieve better design outcomes, but is also an efficient approach for managing the complexity in multi-actor systems. However, it has been recognized that there is a need to identify models of design processes that facilitate rather than prescribe, given the challenging nature of collaborative design (Maher, 1990). By bringing together diverse expertise, we may certainly contribute to the development of a consensus framework. However, the collaborative process is not without its challenges, as conflicts may emerge due to divergent opinions.

In light of these considerations, this paper proposes an approach that offer a flexible and collaborative design process, empowering stakeholders to freely express their preferences and points of view described in the following subsection.

3 BACKGROUND

To understand our approach, knowledge about conflict within collaborative configuration, feature models, and minimal correction subsets (MCSs) is important. They are briefly discussed in the following section.

3.1 Research Hypothesis and Conflict Definition

Research Hypothesis. Let us consider a scenario where practitioners are tasked to evaluate various learning materials (units, activities in textbook) according to learning objectives and given competencies outlined in curriculum. To facilitate this process, practitioners have at their disposal a cartography of criteria, referred to as a configuration, that encompasses a variety of criteria for different scenarios. Practitioners select the configuration of criteria for each unit, ensuring a cohesive alignment with the intended educational outcomes.

So, in this context of collaborative learning materials assessment where multidisciplinary stockholder are involved, conflicting situation may emerge and will likely require unreasonable amounts of time and effort to resolve it. Managing such situation becomes important to optimize human times and efforts.

Basically, according to (Mendonca et al., 2007), a conflict situation occurs when two or more characteristics (in our case, the evaluation of criteria) contain explicit or implicit dependencies rely on the decision state of the other. Likewise, Elfaki et al. (Elfaki et al., 2009) outlined that a conflict occurs when two or more configuration decisions assigned to different stakeholders cannot be true at the same time. Formally, a conflict can be defined as follows:

Definition. *For a given configuration of criteria Cc that comprise a set of configuration decisions $\{Cdi\}$,* *a subset $Cs \subseteq Cc$ is a conflict, if Cc is unsatisfiable and $\forall Cdi \in Cs$, $Cc \setminus \{Cdi\}$ is satisfiable.* A conflict situation can be categorized in different ways. We outline, in the following section, a a classification of different types of conflict.

3.2 Conflict Types

With regard to the classification proposed by (Edded et al., 2020), conflict may be (see Fig.1):

- **Explicit**: that represents the case where the decisions about the same criteria made by two or more stakeholders are contradictory (criteria value selected as "*Extremely High Importance*" selected by a stakeholder and undesired by another selected as "*Extremely Low Importance*").
- **Implicit**: represents the case where the decisions of different experts do not respect the pedagogical constraints. Here, three situations are distinguished:
  - Situation 1: conflict occurs when a criteria A selected by a expert 1 imply an other criteria B which undesirable by expert 2
  - Situation 2: conflict occurs when a criteria A excludes criteria B and both are selected as "*very high important*" by two experts.
  - Situation 3: conflict occurs when two or more criteria cannot coexist and all are selected as "*very high important*" by different experts.

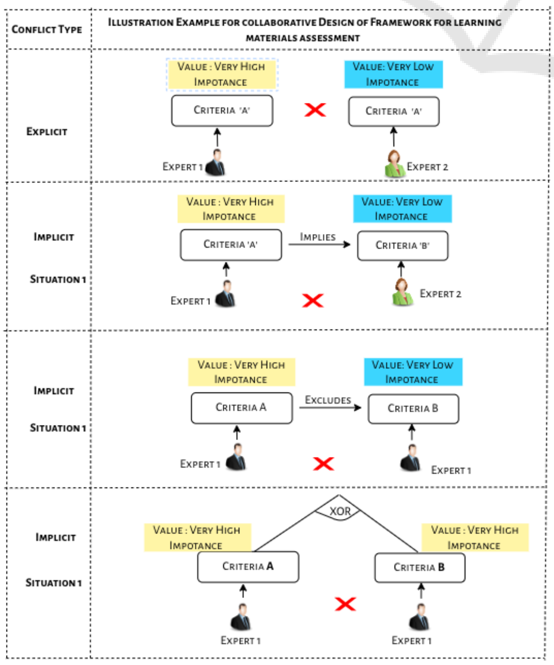

Figure 1: Conflicts types inspired from (Edded et al., 2020).

The organization of criteria cartography follows a hierarchical structure, visually presented using the notation of feature models theory explained in in the following section.

3.3 Feature Models in Software Engineering

Feature models, in software engineering (Apel et al., 2016), serve as specialized information models that comprehensively depict all possible scenarios in terms of features and their relationships. Specifically, a basic feature model organizes features hierarchically, incorporating parent-child relationships categorized as OR, Alternative (XOR), and AND which includes the Mandatory or Optional options. Fig.2 illustrates the graphical notation corresponding to these relationship types (Arcaini et al., 2015).

In addition to these parent-child relations, extra-constraints, such as cross-tree relations, can be introduced to specify feature incompatibilities, notably through expressions like "A requires B" and "A excludes B" (Arcaini et al., 2015). Feature models have become a de facto standard for representing the commonalities and variability of configurable software systems (Feichtinger et al., 2021).

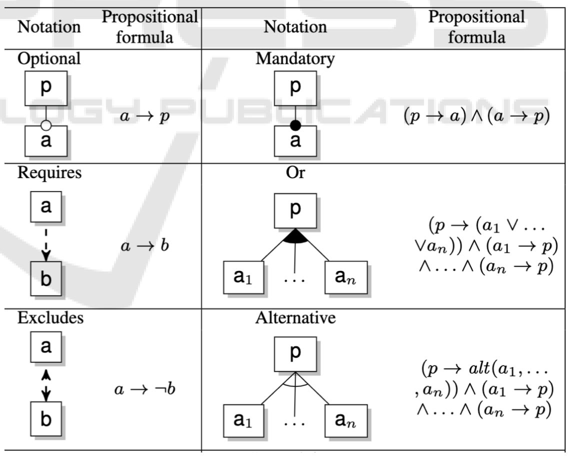

Figure 2: Conventional translation in propositional formulae (Apel et al., 2016).

In our context, we have chosen to embrace feature models, visually represented by feature diagrams, as a concise representation of these intricate scenarios due to their simplicity.

3.4 Minimal Correction Subsets

A Minimal Correction Subset (MCS) refers to a subset of constraints within an infeasible constraint system. Correcting the infeasibility by removing this subset transforms the system into a set of satisfiable constraints. The term '*minimal*' is used to denote that no proper subset possesses this corrective property. It is important to note that an infeasible constraint system may have several Minimal Unsatisfiable Subsets of Constraints (MUSes) and MCSes. Formally, given an unsatisfiable constraint system C, its MUSes and MCSes are defined as follows according to (Liffiton and Sakallah, 2008).

Definition 2. *A subset $N \subseteq C$ is an MUS if N is unsatisfiable and $\forall Ci \in N, N \setminus \{Ci\}$ is satisfiable.* We will refer to individual clauses as Ci, where i refers to the position of the clause in the formula and where each literal a_{ij} is either a positive or negative instance of some Boolean variable: $Ci \bigvee_{j=1..k_i} a_{ij}$

Definition 3. *A subset $F \subseteq C$ is an MCS if $C \setminus F$ is satisfiable and $\forall Ci \in F, C \setminus (F \setminus \{Ci\})$ is unsatisfiable.*

Much research and proposals on computing MCSs have been done in the fields of Boolean satisfiability and constraint satisfaction problems. Their objective is to identify minimal sets of clauses whose elimination transforms a given unsatisfiable Conjunctive Normal Formula (CNF) into a satisfiable one. The idea behind this is to make iterative calls to a Standard Boolean Satisfiability (SAT) solver to check the satisfiability of different sub-formulas. Generally, these algorithms handle a triplet $\{S,U,C\} of F$, where S is a satisfiable subformula, C contains clauses which are inconsistent with S, and U contains the remaining clauses of F.

MaxSAT as represented in (Liffiton and Sakallah, 2008), stands as the most widely adopted approach for computing MCSs that consists of finding an assignment that satisfies the maximum number of clauses of an unsatisfiable formula (Marques-Silva et al., 2013). Consequently, finding MCSs is closely tied to the MaxSAT (or MaxCSP) problem, wherein the goal is to determine a minimal subset of assignments that satisfy the various clauses of an CNF, providing an optimal solution to MaxSAT. This represents an optimal solution to MaxSAT. In this paper, we adopt the approach outlined by (Liffiton and Sakallah, 2008) to calculate MCS in the conflict resolution process within the collaborative design framework.

4 PROPOSED APPROACH

To deal with the issues of the collaborative design framework, we propose a new approach where stakeholders freely express their conception decisions and conflicts are resolved based on their preferences and opinions. A summary of the proposed approach is depicted in Fig.3 . The approach encompasses four main steps: (1) the preference expression, (2) collaborative design, (3) design verification, and (4) conflict resolution based on MUC and utility function.

4.1 Preference Expressing

Preferences of experts, in our case, represent a recovery plan that permit to collaborators to express their preference if one or more of their configuration decisions could not be retained in case of conflict.

Each preference refers to the removal of a specific MCS as illustrated in the example (see figure 1).

In the context of the proposed approach, an MCS represents the set of selected criteria for the assessment framework of the quality of learning materials whose removal makes the current framework satisfiable.

The proposed list, which could be later enriched, is composed of two preferences described as follows:

- Pref1. The most selected clause by collaborators
- Pref2. Decision made by the referent

The referent is a collaborator chosen during the first step of the proposed approach. For each expert Ep (where Ep in $E = \{E1,..,Ez\}$), a reference index is computed based on N features specified by the moderator. For each of these features, a scoring scale has been established to quantify their individual contributions to the overall index.

The alternative selected by the referent (with the higher reference index value) is considered.

In case of conflict, the selected preferences are applied on the list of computed MCS to identify the resolution MCS which is the one common among all these preferences.

This approach helps in systematically resolving conflicts by providing a structured and quantitative basis for decision-making. This can contribute to consensus building and a better understanding of the collective decision.

4.2 Collaborative Design

During the collaborative design step, different stockholders freely express their preference and select a set of criteria composing an assessment scenario towards a given learning materials without being constrained to others scenarios made by the pother collaborators.

In the context of the proposed approach, experts express their opinions about each criteria using the flowing scale:

1. Extremely Low importance (EL)
2. Very Low importance (VL)

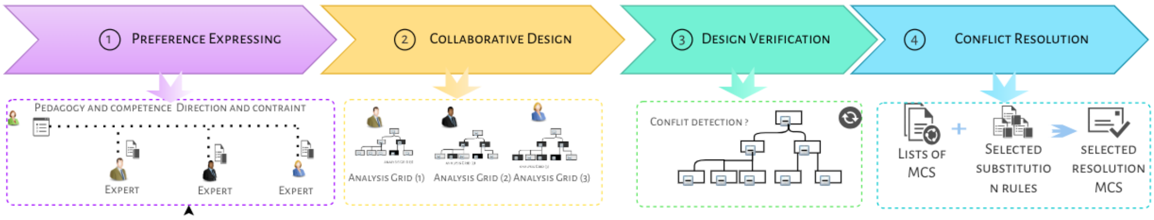

Figure 3: Overview of the proposed approach.

3. Low importance (L)
4. Medium importance (M)
5. High importance (H)
6. Very High importance (VH)
7. Extremely High importance (EH)

A conflict situation may occurs when a given criteria is labeled with (EL or VL or L) and (H or VH or EH) as we illustrate in Fig.1. To streamline the identification of these conflicts, we formally classify experts' opinions into two distinct sets:$F = \{EL, VL, L\}$ and $\neg F = \{H, VH, EH\}$.

4.3 Design Verification

During the verification step, all the proposals are merged: The number of occurrences of each opinion is computed as we illustrate in Fig.4. A binary vector is constructed to check against the list of conflict types described in section 3.2.

The proposal is formulated as CNF where each decision is reprised as a single clause. In case of conflict

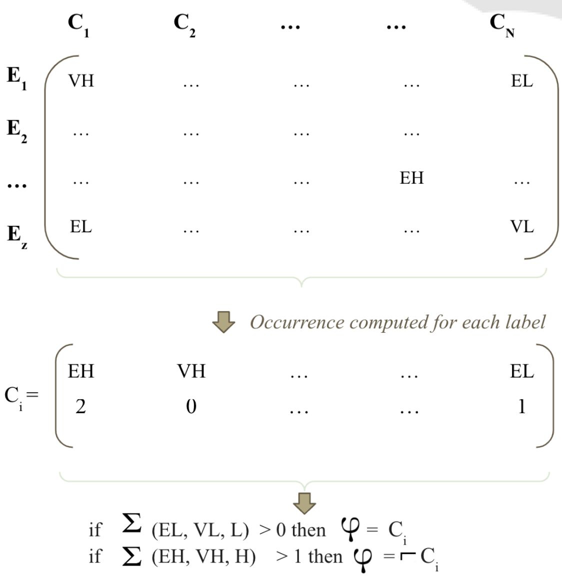

Figure 4: Computing and conversion process of experts' opinions to a CNF problem.

detection, the MAXSAT algorithm of (Liffiton and Sakallah, 2008) is used to compute the list of all the possible MCS for a given unsatisfiable configuration.

Taking into account the set preference selected by the collaborators, the MCS that better meets these preferences is chosen to resolve the detected conflict(s).

4.4 Conflict Resolution

The inputs of the proposed algorithm 1 are the list of preferences selected by the stakeholders (S_preferences), and the list of computed MCSs (List_MCS). As output, the algorithm delivers the MCS of conflict resolution (R_MCS) according to the preference selected by collaborators.

The algorithm selects, at the first step, the list of MCS that eliminates the minimum of metrics to return MCS that encompasses the maximum of metrics (MaxFeatures). This first step may return none or many MCSs.

Therefore, (Result_list) contains the different lists of MCSs returned by the first step. If (Size(Result_list)=1), then this one is returned as a solution (Result_MCS). If (Size(Result_list)> 1), then the function (GetPreference(S_preferences)) returns the most preference (MPref) selected by collaborators. Thus, this preference is applied by Apply(Pref, Result_list) to select an MCS (Resul_MCS) that better respects the preferences of different collaborators.

We provide an illustrative example in the following section.

5 ILLUSTRATIVE EXAMPLE

In the previous section, we introduced our collaborative design framework for evaluating learning materials. In this section, we describe a simple example that illustrates the proposed approach, namely how conflicts can be resolved during the design process using our algorithm. Firstly, we introduce the adopted cartography of criteria. Secondly, we showcase an illustrative example using the developed supporting tool.

Data: S_Preferences: list of Preference selected by stakeholders. ;
List_MCS: list of computed MCSs.
Result: Result_MCS: conflict resolution's MCS.
Result_list ← MaxFeatures(List_MCS);
read current;
if *(Size(Result_list)=1)* **then**
  Result_MCS ←Result_list ;
else
  MPref ←(GetPreference(S_preferences));
  Result_MCS ←Apply(Pref, Result_list);
end
Return(Result_MCS);

Algorithm 1: Algorithm of Conflict Resolution based on Experts' preferences.

5.1 Learning Design Materials: Direction and Constraint of Pedagogy and Competence

The adopted framework is inspired by (Ferrell, 1992) to evaluate the quality of the designed learning materials. Here, there are some common criteria:

- **Instructions of the Given Learning Material.**
  - **Clarity of Instruction.** Learning materials should be written in a clear and accessible language, facilitating student comprehension.
  - **Diversity of Instruction.** Learning materials should include effective pedagogical features, such as exercises, examples, and activities, to reinforce learning.
- **Responsiveness of Learning Needs.** The leaning materials should align closely with the learning needs curriculum and learning objectives of a course or programming particular and with educational standards and guidelines in general .
- **Flexibility.** Learning materials should cater to the needs of diverse learners, including those with different learning styles and abilities. Evaluation helps ensure that the textbook is inclusive and can be effectively used by a broad range of students.

The assessment of a learning activity typically is centred around a specific competence in competency-based learning. In this paper, we take scientific reasoning competencies as an illustrative example. Scientific reasoning, considered an advanced skill, can be composed of complex combinations of practices, rudimentary skills, and intermediate competencies. It encompasses various types of thinking such as computational, mathematical, engineering, design and system thinking, needed to enhance citizen real life experience. These experiences may involve activities such as critiquing a situation, solving problems, or proposing feasible solutions.

Problem-solving, a key facet of scientific reasoning, can manifest in both individual and collaborative settings. Drawing upon this overarching framework and leverage an existing criteria framework, we extrapolate a non-exhaustive configuration model for evaluating the quality of a learning activity.

Fig.5 offers a snapshot of this cartography, offering a visual insight into the derived model as represented by feature diagrams.

5.2 Collaborative Design Using the Supporting Tool "EduColl"

Considering that three collaborators are sharing this cartography of the assessment framework model, a popularity order is computed and assigned to the different stakeholders. Afterwards, each collaborator tags the framework criteria switch to the learning activity to be assessed. The table 1 resumes the preference of each collaborator and their reference index.

Table 1: Preferences of each collaborator.

Expert	Reference index	Preference
E1	2	Pref.1
E2	3	Pref.2
E3	4.5	Pref.1

The total design encompasses all the labels of different criteria made by the different stakeholders. Subsequently, the total consistency of the conception is checked against the dependencies of the feature model depicted in the third column of the table 2.

After the verification of the obtained configuration, three conflicting situations are detected. The initial conflict arises due to the labeling of the '**Discussion with teams**' criteria as **VHI** in the '**problem resolution**' category. This designation conflicts with the exclusionary label of '**individual work**,' which is marked as **EH**. The second conflict emerges when both the '**individual work**' is labeled as **VH** and the '**collaborative work**' is also marked as **VH**. A third conflict materializes when both '**Divergent creativity**' and '**analogical reasoning**' are concurrently selected with the VH designation.

To address these conflicts, Minimal Correction Subsets (MCSs) are calculated. The initial phase of our algorithm involves the elimination of C1, which excludes C2 and C4. Subsequently, the algorithm faces the decision between C5 and C6, opting for the switch that aligns with the most frequently chosen

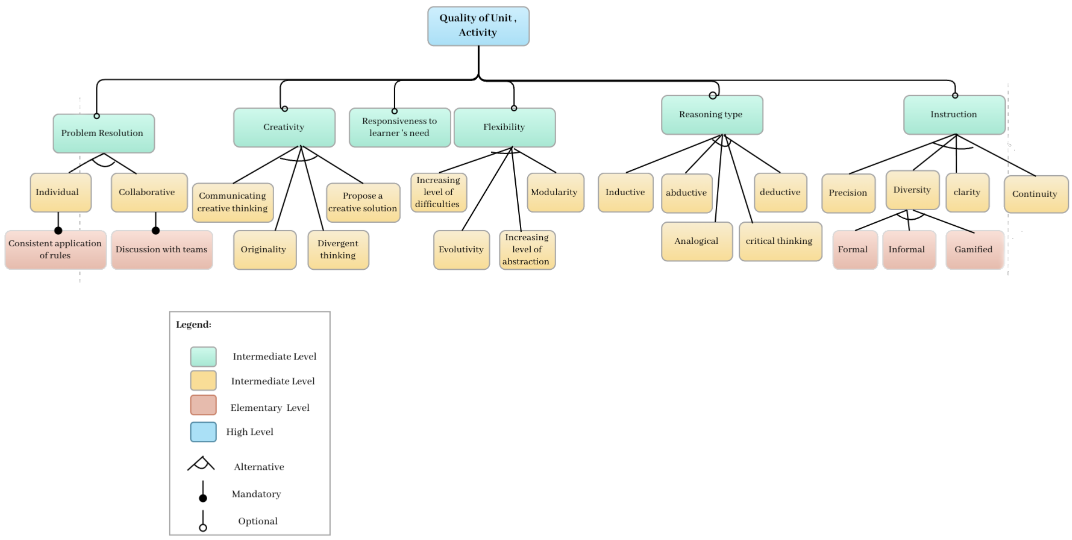

Figure 5: Criteria framework modelled according to feature models.

Table 2: Preferences of each collaborator.

Ref.	Clauses	Constraints	Violated Constraints
C1	Individual is VH	$C1 \longrightarrow \urcorner C4$	$\varphi = C1 \wedge C2 \wedge C3 \wedge C4 \wedge C5 \wedge C6$
C2	Discussion with them is VH	$C1 \longrightarrow \urcorner C2$	
C3	Critical thinking is EH	$C2 \longrightarrow C3$	
C4	Collaborative is VH	$C4 \longrightarrow \urcorner C1$	
C5	Divergent creativity is VH	$C5 \longrightarrow \urcorner C6$	
C6	Analogical reasoning is VH		

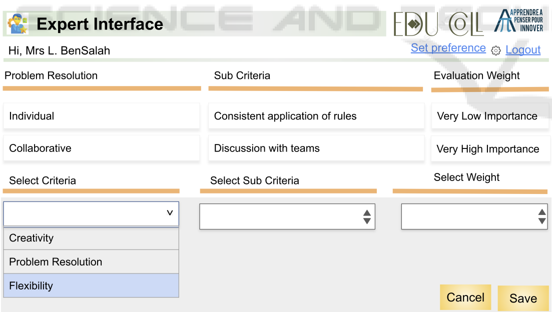

Figure 6: The expert Interface.

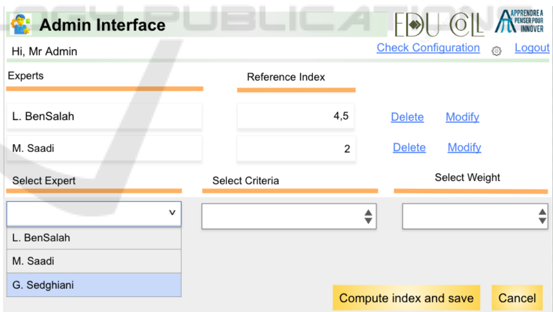

Figure 7: The administrator interface.

preference. In this particular scenario, stakeholders have expressed a greater preference for Pref.1. Examining the vectors for $C5 = (1,1,0,0,0,1,0)$ and $C6 = (1,0,0,0,1,1,0)$, it becomes evident that the importance is assigned to C5.

To assess the viability of the proposed approach, we implemented a tool named *EduColl*, utilizing a microservice-based web application architecture. *EduColl* provides various user interfaces to cater to different needs. The first interface is tailored for collaborators, allowing them to select preferences and express opinions regarding various criteria, as illustrated in Fig. 7. The second interface is designed for administrator, who manages participating stakeholders (refer to Fig. 6) by assigning reference indices and verifying the overall configuration's consistency, as depicted in Fig. 6. The administrator is entrusted with overseeing conflict resolution and ensuring that the final validated configuration is delivered to stakeholders.

6 CONCLUSION AND FUTURE DIRECTIONS

The evaluation of learning materials used in learning situation provides valuable feedback to different stockholders practitioner, publishers, and educators. This feedback loop supports their iterative improvement, allowing for updates and revisions based on the evolving needs of learners and changes in the educational landscape.

We consider that in the future several controlled experiments must be conducted to assert the usefulness of this work.

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