Supporting Educators to Design Collaborative Learning Scenarios

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Abstract: Collaborative learning (CL) processes are not always effective and the inadequate design of CL scenarios is one of the main causes of its unsuccess. Designing CL scenarios is a complex task, since it involves countless requirements and constraints that affect learning process and, hence, the learning outcomes. Consequently, CL scenarios are usually inappropriately structured. This study is particularly interested in the complexities inherent to the process of designing CL scenarios. Its objective is to propose a framework, composed of a conceptual metamodel and a computational tool, in order to support/guide educators throughout the process. The proposed framework was evaluated through a case study with 22 professors of a federal university. The results showed that with the framework it is possible to expose educators to design parameters in a way that they can effectively and systematically be specified.

1 INTRODUCTION

There is an increasing interest in providing learners with collaborative learning (CL) scenarios in order to support them acquire and develop their knowledge and skills (Isotani et al., 2013). However, the simple fact of putting learners working together does not ensure effective learning (Weinberger et al., 2009). Studies stressing the potential of such scenarios show that the chance for having meaningful and also lasting learning diminishes considerably when they are not appropriately designed (Isotani et al., 2010). In fact, the inadequate design of CL scenarios is one of the main causes of unsuccessful group learning (Strijbos et al., 2004; Dillenbourg, 2002).

Designing CL scenarios is a complex task, since it involves countless requirements and constraints (King, 2014). Well-designed CL scenarios must be structured based on learners' learning characteristics and needs, and considering the necessity of guidance for learners' actions and interactions. Moreover, they must be structured in a way that enables educators to perform monitoring, analysis and evaluation of the learning process accurately – mainly considering the learner, individually. In a broader sense, the difficulty is to transform all aforementioned issues into elements that structure a scenario. Therefore, due to the complexities inherent to the process of designing CL scenarios, educators do not perform a thorough planning. The process is particularly challenging for (but not limited to) novice educators – since, in most cases, they do not have all necessary knowledge and experience (Isotani et al., 2013). Consequently, such scenarios are improperly structured (Barkley, 2014; Höver and Mühlhäuser, 2014).

In this paper, the research problem refers to the lack of adequate design of CL scenarios. The goal is to provide an infrastructure able to guide and support educators in the process of designing such scenarios. A design framework was implemented as a proposed solution to the presented problem. A case study was carried out in order to evaluate the framework.

The following sections initially discuss some approaches to structuring collaborative learning scenarios. Then, in section 3, a set of design principles is presented – defined in order to guide educators when designing CL scenarios. Section 4 presents some results of our previous research. Section 5 presents the framework, describing its content and implementation. Section 6 presents the evaluation of the framework, carried out through the aforementioned case study. The results are presented in section 7. Finally, section 8 presents the conclusions of this study.

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2 APPROACHES TO DESIGNING CL SCENARIOS

Many approaches have been proposed in order to support educators in structuring CL scenarios. One of them refers to the concept of collaborative scripts. Conceptually, a collaborative script (CS) corresponds to a set of instructions related to how members of a group work should interact, collaborate and solve a specific problem (O'Donnel and Dansereau, 1992). So, a CS is a collaborative instructional scenario that organizes the activities and actions inherent to the learning process.

Another approach, specifically within the CSCL community, consists of CSCL patterns (an initiative particularly aimed at the reuse of artefacts – i.e., practices, techniques etc.). Formally, a pattern is a strategy of organizing information about a common problem and its solution, enabling it to be repeatedly used. CLFP[1] patterns (Hernández, 2006) are examples of collaborative learning patterns. Specifically, they aim to document techniques to organize the sequence of collaborative activities included in CL scenarios.

In line with these patterns, there are the collaborative learning techniques (CoLTs). Barkley et al. (2014) present several of these techniques, describing them as artefacts that provide instructions for engaging the learners in CL processes.

Another approach consists of instructional design models, defined as a set of activities (previously sequenced) to be followed by educational designers for the design of CL scenarios. Most of the existing models have similar elements, varying in the number and/or terminology of their phases. ADDIE (Jonassen et al., 1999) is an example of an instructional design model.

Despite several approaches, all of them have limitations. Regarding collaborative scripts: (a) there is no reference model for their specification; and (b) there is also a lack of guidance about how educators should specify the script elements. The limitations of collaborative patterns are: (a) they have instructions, activities etc. predefined – therefore, imposing a limitation in relation to their flexibility (be structured according to educators' needs and intentions), and (b) there is a considerable number of patterns (thus, imposing on educators the need to know several patterns in order to be able to choose those that best suit one's needs). Finally, regarding the design models, it is observed that (a) they do not include specific rules, guidelines and instructions (they only present general guidelines – thus, not defining how the activities they establish should be carried out).

Due to the complexity of designing CL scenarios, computational tools capable of supporting it become essential. Challco et al. (2016) performed an analysis of some of these tools. Despite the diversity of tools, there are also limitations in them. In fact, in general, they (a) do not provide any guidance to the educators (i.e. how the design process should be carried out), and (b) they are restricted to specific models, limiting their flexibility. Therefore, it is observed that all the aforementioned approaches have limitations related to the ability to guide and support educators through the design process, as well as to their flexibility.

3 DESIGN PRINCIPLES

Although there are many proposals to the problem of inadequate design of CL scenarios, all of them have limitations (mainly regarding the support provided to educators when carrying out a design). Due to these limitations, and considering our interest in providing educators with proper support/guidance, we directed efforts in a previous study (Oliveira and Borges, 2019) towards identifying the (most) relevant elements to the design process. From these elements, a set of twelve **design principles** was specified (i.e. recommendations with the purpose of guiding educators throughout the process), presented in table 1.

Table 1: Design principles.

Design Principles
1 - Learning Objective (Work)
2 - Learning Objective (Learner)
3 - Group Formation
4 - Activity Specification
5 - Activity Suitability
6 - Activity Division
7 - Collaboration
8 - Monitoring (Work Development)
9 - Monitoring (Learning Process)
10 - Activity Guidance
11 - Support Material
12 - Learning Evaluation

Considering the **learning objective (work)**, it is recommended that its specification occurs not only at the level of the entire work and its phases, but also at the level of its activities. In fact, when the objectives are defined for the work activities, learners have the chance to better manage their achievement. Besides, it is possible for the educator to carry out assessment and monitoring processes in a more precise way, and also to have a clearer perception about the specific purposes of these activities.

[1] Collaborative learning flow patterns

Regarding the **learners' learning objectives**, it is recommended that they be specified for the learners (individually). In this way, enabling the educator to monitor and assess the learning of each learner in a more precise way.

Regarding the **formation of group**, in order to avoid inappropriate composition of groups, the active participation of the educator is recommended (with the educator taking responsibility for the process or guiding the learners through it).

Regarding the **specification of activities**, it is recommended that they be defined with a high level of granularity (i.e., more specific activities). This not only facilitates the specification of their parameters (objectives, deadlines etc.), but also enables the educators to perform assessment and/or monitoring processes more accurately.

Regarding the **suitability of activities,** although it is important to design the activities according to the characteristics of groups or classes (educational needs, level of knowledge etc.), it is recommended that they be designed considering individual learners' characteristics and needs.

Regarding the **division of activities** among group members, the active participation of the educator is recommended in order to avoid that the process occurs improperly (for example, learners being responsible for activities they consider easier) or unequally (i.e., few members being responsible for most of the tasks).

Concerning the **collaborative process,** it is also recommended that educators guide it. This understanding is based on the premise that learners working in groups in a free collaboration environment do not always provide satisfactory results; in general, they do not have an accurate understanding of the collaborative process, neither of how to behave and learn in environments that employ it.

About the **development monitoring**, although it is essential to monitor the development of the work and its phases, it is recommended that it is carried out at the activity level (making it possible to obtain more precise information that is essential to the management of the process, by both learners and educator).

Regarding the **learning monitoring**, it should be performed through careful observation. Besides, it is important to previously specify goals, analysis points etc. In addition, it should be done at the level of the learners, so that the educator is clear about the individual evolution of each one throughout the educational process.

As to the **activities guidance,** it is recommended that educators support/guide learners to accomplish the activities, since in general they do not carry out collaborative tasks in an adequate way. It is assumed that poor learner guidance during a learning process is significantly less effective than a specifically designed guidance. Therefore, the educator should guide learners on the organization/management of their actions during the development of activities – thereby, supporting them to achieve the learning objectives.

It is also recommended that educators provide **support material**. Although it is important that the material assists students in the development of the work (and its phases), it is recommended to provide materials that assist students in the development of each task – thus, helping them in a more specific way.

Regarding the **assessment of learnin**g, although it is important that it is carried out at the level of the groups, as well as based on the final results developed by them, it is recommended that it is carried out at the student level (individually) and throughout the work development.

3.1 Analysis Framework

In order to enable the analysis of the design of CL scenarios implemented by educators in an instructional environment, an analysis framework – based on the aforementioned design principles – was developed in our previous work. For each design principle, three alternatives were specified (a, b and c); for each one, a valuation score was defined, with the scores "0" (does not meet the principle), "0,5" (partially meets the principle), "1" (fully meets the principle). Table 2 presents a piece of the developed framework.

Table 2: Part of the analysis framework.

1 – Learning objectives (work)		
a	The educator does not specify the learning objectives	0
b	The educator specifies the learning objectives through abstract elements; the objectives are specified to the whole work, its phases or its individual activities	0,5
	The educator specifies the learning objectives through formal elements; the objectives are specified to the whole work	
c	The educator specifies the learning objectives through formal elements; the objectives are specified to work phases or to the work activities (individually)	1

4 CL SCENARIOS DESIGN: AN ANALYSIS

The aforementioned framework was used to analyze the results of an exploratory study, also presented in our previous work. The objective was to analyze the adherence of the design carried out by educators to the 12 design principles. The study observed whether and how educators of higher education (particularly, in the computer science domain) design group work scenarios while teaching undergraduate courses. Personal and semi-structured interviews were conducted with 30 professors from the computer science department of a federal university. The sample was composed of 27 professors with doctor's degree and 3 with master's degree. Regarding the teaching experience (in years) in higher education, 6 professors had less than 5 years, 7 had between 5 and 10, 5 had between 11 and 15, 8 had between 16 and 20, 2 had between 21 and 30, and 2 had more than 31.

Of the 30 educators, 22 answered they use group work practices while teaching an undergraduate course. Thus, according to their answers to the interview, a score ("0", "0,5" or "1") was obtained for each of the 12 design principles. For each educator, the scores were added up, obtaining a total score, which represents the level of adherence of the design implemented by the educator. In order to assess the level of adherence, a classification score (presented in Table 3a) was defined. Table 3b presents the educators' classification. The 22 educators are identified as P1 to P22.

Table 3: Educators' design adherence.

Classification	Total Score
Null	0
Insufficient	0 < score ≤ 4
Regular	4 < score ≤ 8
Good	8 < score < 12
Excellent	12

(a)

Educator	Score	Classification
P13	4,5	Regular
P3		
P6		
P2	3,5	Insufficient
P11		
P4		
P5	3	
P17		
P1	2,5	
P9		
P15		
P16		
P20		
P12		
P14	2	
P21		
P18	1,5	
P7	1	
P8		
P10		
P19		
P22	0	Null

(b)

The results show that, of the 22 educators, 18 implement an insufficient design; 3 implement a regular design; and 1 educator implements a design whose adherence level is null. It was also observed that of a possible maximum score of 12, the best-evaluated educators achieved only 4.5. The results expose a set of deficiencies regarding the design of group work scenarios implemented by the 22 educators. In fact, they do not specify several of the important elements to the design process. The results reinforce the necessity of providing educators with useful and proper support/guidance when designing CL scenarios, helping them to both understand these elements and specify them.

5 DESIGN FRAMEWORK

Considering that the proposal of this study is to guide and support educators to appropriately design CL scenarios, the solution consists of a design framework, which is composed of (i) a design metamodel and (ii) a computational tool. The first one refers to a structure that conceptualizes the domain of CL scenarios design, based on the design principles mentioned in section 4. The second one consists of a computational infrastructure to support the metamodel, making possible its use by the educator when carrying out a design. Basically, the workflow consists of specifying the elements of the metamodel, according to the educator's instructional intentions, generating a particular CL scenario that expresses them.

5.1 Design Metamodel

The design metamodel includes a set of basic concepts – which characterize the basic structure of a group work –, and a set of concepts based on the design principles. Figure 1 presents it.

The design metamodel is composed of 14 concepts – or macroelements. The basic structure of a group work (project) comprises the macroelements: Project, Section, Practice and Module. According to the metamodel, a project is composed of modules (topics explored in the project) and sections, in which practices (development of learning activities) are performed by learners. Practices can be sequenced and/or related by the educator through an activity structure.

Learners or groups perform practices, and learners can play specific roles. Learning objects can be used in order to support the execution of practices. Monitoring activities can be specified to monitor

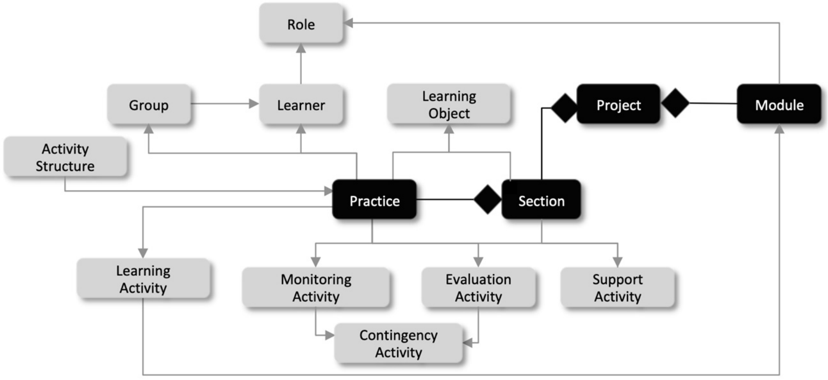

Figure 1: Design metamodel.

practices or sections. Evaluation activities can be defined to enable the assessment of practices or sections. Educators can assist the development of practices or sections through support activities. Contingency activities correspond to actions/tasks to be performed as a result of some specific condition identified by the educator, through a monitoring or evaluation activity.

The definition of the aforementioned elements was based on the design principles. As an example, the macroelements proposed in order to meet the Learning Objective (project) principle were: Project, Section and Learning Activity. All of them comprise parameters that enable the educator to specify the general objectives of the work, the objectives of its sections and the objectives of each learning activity. Figure 2 shows the parameters of the Project macroelement.

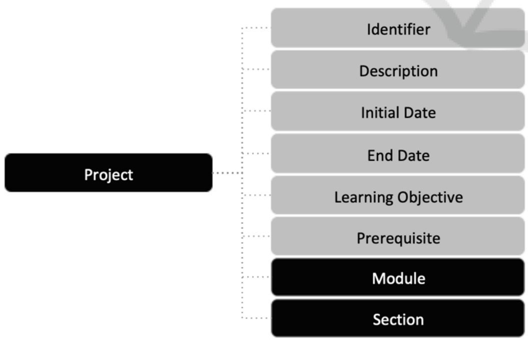

Figure 2: Parameters of the project microelement.

Besides the basic parameters (light gray), Module and Section macroelements integrate the Project macroelement, indicating that a project has modules and sections.

For the specification of the design metamodel, XML language was used. It provides a free and practical strategy for the definition of information, as well as its representation in hierarchical structures, adding semantic levels capable of conferring significant power of expression. The option for XML also considered the fact that it is a technology-independent language – therefore, there is no need of a specific software to read and interpret XML files. A fragment of the XML Project macroelement is presented in figure 3.

```
<project-design identifier="Project 01">
   <description></description>
   <initial-date></initial-date>
   <end-date></end-date>
   <learning-objective></learning-objective>
   <prerequisite></prerequisite>
   <module identifier="programming"></module>
   <section identifier ="Phase 01"></section>
</project-design>
```

Figure 3: XML Fragment of the project microelement.

5.2 Computational Tool

The computational tool aims to provide support for the use of the design metamodel, guiding the educator with regard to the analysis and specification of its elements. Therefore, the development of the tool was carried out in order to support the educator in specifying the 12 design principles.

The tool provides a set of functionalities, grouped in 6 categories: create (create/register elements in a project), edit (complement and/or modify information of elements registered in the project), view (visualize information of elements registered in a project and relationships between elements), include (class of actions that enables educators to relate elements; for instance, include learning object in a section), assign (relate elements in a project – for instance, assign role to learners) and delete (class of actions that enables the educator to delete an element of the project or "disconnect" related elements).

For the development of the tool, object oriented programming paradigm and PHP programming language were adopted. Regarding the architecture, the tool was structured as a monolithic Web application, using a multilayer architecture. Figure 4 presents a screen (in Portuguese) of the tool related to the creation of practices.

6 FRAMEWORK EVALUATION

The evaluation aimed to analyze the CL scenario design process carried out by educators in their face-to-face undergraduate courses (in the computer science domain). The purpose was not to evaluate if the design supports the educator in conducting the learning process or if it promotes learners' learning. Actually, the goal was to evaluate the perception of educators regarding the guidance and support provided by the framework and the adherence of the design implemented by them to the design principles. Although it is important to analyze the effectiveness of the design in supporting educators in conducting the learning process, as well as fostering the development of learners' learning, these are issues to be addressed in future works.

This study adopted the case study as research methodology. According to Yin (2015), a case study consists of an empirical investigation that studies a contemporary phenomenon in depth and in its real-world context. The case study is presented as the preferred method in situations in which it is necessary to answer questions such as "how" or "why", when the researcher has little or no control over the investigated event and when the focus of the study is a contemporary phenomenon.

Particularly, our study proposes to investigate how the design of collaborative learning scenarios can be carried out to promote its adherence to the design principles. In addition, given the characteristics of the event of interest, the researcher has no control over it. In fact, the study focuses on investigating real situations of design of CL scenarios by educators. In this context, considering that design is a task inherent to the educator, as well as the environment in which he/she is inserted, the researcher has no interference or control over the studied event.

6.1 Case Study

For this study, the approach of multiple case studies was adopted, with multiple units of analysis defined for them. The choice was appropriate since it makes it possible to carry out a comparative analysis of the cases, allowing a broad view of the studied phenomenon.

The definition of the cases, as well as of the units of analysis (or educators), was based on the results obtained from the exploratory study carried out in our previous research (Oliveira and Borges, 2019). For this study, three cases were defined. **Case 1** includes the educators whose designs were not adherent to the design principles (when compared to the results of other educators). **Case 2** comprises the educators whose designs were moderately adherent. **Case 3** includes the educators whose designs were adherent to the design principles.

The definition of the units of analysis was based on the scores (level of adherence) presented in table 3. Three units of analysis were selected for each case. This number was based on Yin (2015) – according to him, in projects of multiple cases, it is necessary

Figure 4: Creation of a practice.

to have at least two individual units in each case. The selected units are presented in Table 4.

Table 4: Selected units of analysis.

Cases	Selected Educators	Adherence
1	P22	0
	P19	1
	P18	1,5
2	P14	2
	P20	2,5
	P16	2,5
3	P17	3,0
	P2	3,5
	P6	4,5

The data collection protocol of the case study comprises 3 phases. **Phase 1** consists of analyzing the results of the exploratory study (performed in our previous research). **Phase 2** consists of the design of CL scenarios. Particularly in this phase, the educators of cases 1, 2 and 3 use the proposed framework to design CL scenarios. Before this phase 2, the researcher presented a workshop in order to explain the case study as well as the computational tool to the educators. All educators had six weeks to complete the design. At the end of phase 2, the researcher performed an analysis of the design carried out by the educators in order to evaluate its adherence to the design principles. **Phase 3** consists of a personal and semi-structured interview with each educator. The purpose of this interview was to analyze the perception of the educators in relation to the use of the proposed framework.

7 RESULTS

Table 5 presents the comparative results between the 3 units of analysis (P18, P19 and P22) in **case 1**. These results show that all educators achieved a higher level of adherence (total score) – when comparing the scores related to the design without using the framework and using it. Therefore, the framework was able to support all educators in carrying out a CL design more adherent to the design principles.

Table 5: Adherence level comparison – case 1.

	Total Score Without Framework	Total Score Using Framework
P18	1,5	8
P19	1	5
P22	0	5,5

Table 6 presents the comparative results between the 3 units of analysis (P14, P16 and P20) in **case 2**. Similarly to case 1, all educators achieved a higher level of adherence (comparing the scores associated to the design without using the framework and using it). Also for this case 2, the framework was able to support all educators in carrying out a CL design more adherent to the design principles.

Table 6: Adherence level comparison – case 2.

	Total Score Without Framework	Total Score Using Framework
P14	2	5,5
P16	2,5	7,5
P20	2,5	6,5

Table 7 presents the comparative results between the three units of analysis (P2, P6 and P17) in **case 3**. Similarly to cases 1 and 2, all educators achieved a higher level of adherence. Therefore, the framework was also able to support all educators in carrying out a CL design more adherent to the design principles.

Table 7: Adherence level comparison – case 3.

	Total Score Without Framework	Total Score Using Framework
P2	3,5	7
P6	4,5	6
P17	3	6,5

Table 8 presents the comparative results among the cases 1, 2 and 3.

Table 8: Adherence level comparison – cases 1, 2 and 3.

	Case 1			Case 2			Case 3		
	P18	P19	P22	P14	P16	P20	P2	P6	P17
Without Framework	1,5	1	0	2	2,5	2,5	3,5	4,5	3
Using Framework	8	5	5,5	5,5	7,5	6,5	7	6	6,5
	Total Score – educator								

Without Framework	2,5	7	10,5
	Total Score per Case (sum of teachers' grades – per case)		
Using Framework	18,5	19,5	19,5
	Total Score per Case (sum of teachers' grades – per case)		

It is possible to observe, for all cases (1, 2 and 3), an improvement in terms of adherence to the design principles – when comparing the scores of educators without using the framework and using it. For **case 1**, the total score (sum of the scores of educators P18, P18 and P22) increased from 2.5 to 18.5. For **case 2**, the score increased from 7 to 19.5. For **case 3**, the score increased from 10.5 to 19.5.

These results show that the framework had a greater impact in case 2 (lower level of adherence) and less impact in case 3 (greater level of adherence). It is noted, therefore, that in the cases in which educators presented more expressive difficulties in terms of design (without the use of the framework), the proposed framework presented greater support capability (to carry out a design more adherent to the design principles). On the other hand, the lower this difficulty for educators (analyzing the cases, as a whole), the lower the support capability provided to them by the framework.

Table 9 presents the results for two of the many questions present in the interview carried out in phase 3 of the data collection protocol. Question "a" asked the educator if the framework provides adequate support for the design of CL scenarios. Question "b" asked whether the educator, based on the experience of using the framework, changed his/her perception of how to design CL scenarios.

Table 9: Answers to (some) interview questions.

		Question “a”		Question “b”
Case 1	P18	Yes	High	Yes
	P19	Yes	High	Yes
	P22	Yes	Moderate	Yes
Case 2	P14	Yes	Moderate	Yes
	P16	Yes	High	Yes
	P20	Yes	High	Yes
Case 3	P2	Yes	High	Yes
	P6	Yes	Moderate	Yes
	P17	Yes	High	Yes

The results show that, for question "a", all educators answered that the framework provided moderate to high support and guidance in order to assist them in specifying the design elements – that is, in designing CL scenarios. Similarly, for question “b”, all educators answered that the experience of using the proposed framework was able to change their view regarding how to design CL scenarios, in a positive way. For all these educators, the framework made it possible to specify several design elements that they did not consider when planning their group work scenarios.

8 CONCLUSIONS

Careful planning is essential to the effectiveness of collaborative learning processes. However, the planning process of CL scenarios is complex; therefore, they are usually inappropriately and inefficiently structured, making it difficult for students to achieve learning objectives.

Previous studies indicate the need to provide educators with useful and proper support and guidance, exposing them to parameters and processes that should be accounted in the CL scenarios design process. In this study, it was investigated how educators perform designing of CL scenarios while teaching an undergraduate course in the computer science domain. A design infrastructure was developed and evaluated through a case study with 22 professors of a federal university.

The results showed that the framework was able to support and guide all educators in carrying out a collaborative learning design more adherent to a set of design principles (a set of recommendations with the purpose of guiding educators throughout the CL design process).

As future work, it is intended to analyze whether and how the framework is able to support educators in conducting the learning process. Moreover, it is proposed to investigate the impact of the framework on learners’ learning.

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