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ORIGINAL RESEARCH

Analyzing a Computational Infrastructure for Supporting the Design of Group Learning Scenarios

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Abstract

Collaborative learning (CL) processes are not always effective and inadequate design of CL scenarios is one of the main causes of its failure. Designing CL scenarios is a complex task, since it involves countless requirements and constraints that affect the learning process. A previous study showed that educators, in general, perform an inappropriate design of CL scenarios—failing to specify essential parameters and processes, mainly regarding the guidance of the learners' actions and the evaluation of their learning. This indicates the need to provide educators with proper support and guidance. This study is particularly interested in providing a computational infrastructure to support and guide educators throughout the design process. The proposed infrastructure was evaluated through a case study with a sample of professors at a university in real situations of group work design in their face-to-face undergraduate courses. The results showed that, for this sample of educators, the infrastructure was able to expose them to relevant design parameters, supporting them in their specification and helping them to understand these parameters. Therefore, the infrastructure shows potential to prevent CL scenarios from being inappropriately and inefficiently structured.

Keywords Collaborative learning · Learning scenarios · Learning design tools

Introduction

Learning processes are not always effective [1], even when collaborative learning (CL) strategies are used [2]. This means that knowledge and skills development/acquisition goals are not always achieved. It is a fact that there is an increasing interest in providing learners with collaborative learning scenarios that help them to acquire and develop their knowledge/skills [3]. However, the simple action of putting individuals working together does not ensure effective learning [3]. Educators are expected to create scenarios that not only keep learners actively involved in working to develop their knowledge, but which are challenging, motivating and adapted to them. Studies stressing the potential of CL scenarios show that the chance of having meaningful and lasting learning diminishes considerably when they are not appropriately designed [4]. In fact, the inadequate design of CL scenarios is one of the main causes of unsuccessful group learning [5, 6].

Designing CL scenarios is a complex task, since it involves countless requirements and constraints [7]. Well-designed CL scenarios must be structured based on learners' learning characteristics and needs, and considering the necessity to guide 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 [8–10]. However, educators often and mistakenly understand CL as any activity in which learners work in groups. Therefore, in most cases, they simply ask learners to work in groups, without any suitable preparation [11]. As a result, CL scenarios are improperly and ineffectively structured [11, 12]. In a broader sense, the difficulty is to transform all aforementioned issues into elements that structure a scenario. This is a particularly challenging

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process for—but not limited to—novice educators, since, in most cases, they do not have all necessary knowledge and expertise [13]. In fact, many educators do not feel prepared to design such scenarios [14, 15]. Chikh [16] corroborates it by mentioning that many of the intrinsic concepts of the process are unknown by many educators.

In this sense, this study deals with the problem of designing CL scenarios without careful planning. We argue that, in general, educators do not perform the design of CL scenarios taking into account the specification of important parameters (learning objectives, tasks sequencing and assignment, monitoring, evaluation, etc.). This premise was the object of a previous study [17] in which we observed its occurrence in a sample of educators. Thus, it is crucial to provide educators with proper and useful guidance and support. The goal of this study is to provide an infrastructure able to guide and support educators throughout the process of designing CL scenarios, exposing them to relevant design parameters and supporting them in their specification. The study was carried out under the case study methodology, with a qualitative and exploratory approach. It was based on the hypothesis that this infrastructure provides educators with proper support and guidance when designing CL scenarios, helping them to understand the relevant design parameters and to specify them. Both the proposed infrastructure and the case study to evaluate it were described in a previous paper [19]. This study aims to discuss them in more detail, in addition to presenting relevant new results.

CL Scenarios Design: Related Approaches

Many approaches have been proposed in order to support educators in structuring CL scenarios. Collaborative scripts [21], collaborative patterns [11, 22] and instructional design models [23] are some of them. In summary, collaborative scripts correspond to a set of instructions related to how members of a group work should interact, collaborate and solve a specific problem. Thus, they are scenarios that organize activities and actions inherent to the learning process. Collaborative patterns aim to document techniques to organize the sequence of activities included in CL scenarios. Once structured as patterns, the techniques can be repeatedly used. Instructional models are defined as a set of activities (previously sequenced) to be followed by educators for the design of CL scenarios. In addition to these approaches, there is a set of computational tools developed with the purpose of supporting educators throughout the design process.

Despite several approaches, all of them have limitations—regarding the support and guidance provided to educators and their flexibility. In relation to collaborative scripts, there is no reference model for their specification, and there is also a lack of guidance on how educators should specify the script elements. Existing proposals are limited to presenting their parameters. Regarding collaborative patterns, their instructions and activities are predefined—therefore, imposing a limitation in relation to their flexibility (being structured according to the educator's intentions and needs). Furthermore, there are a considerable number of patterns (with specific proposals), imposing on educators the need to know several of them in order to be able to choose those that best suit one's needs. In relation to the design models, it is observed that they do not include specific instructions (they present general guidelines, not defining how the activities should be carried out). Regarding computational tools, despite their diversity, there are also limitations. In fact, in general, they do not provide any guidance to the educators (i.e.: how the design process should be carried out), and they are also restricted to specific models, limiting their flexibility. In [24], an analysis of several of these tools was performed.

The limitations presented by current approaches/tools reinforce the need to provide an infrastructure capable of properly supporting/guiding educators in the design of CL scenarios.

Methodology

In this section, the methodology adopted in this study is described: the background, the infrastructure to support the design of CL scenarios, and the case study carried out to evaluate it.

CL Scenarios Design: An Analysis

The literature is clear about the responsibility of educators to provide learners with an effective learning experience [18] and the consequences of carelessness in planning CL processes. In fact, it is hard to imagine that a CL situation can be effective in its purpose if educators fail to provide learners with adequately structured scenarios. Thus, we directed efforts in a previous study [17] towards investigating how educators of higher education carry out designing of group work activities while teaching face-to-face undergraduate courses.

Initially, as a result of a literature review, we identified the most relevant elements to the design process. From them, a set of 12 design principles (recommendations with the purpose of guiding educators on how to specify these elements) was defined. From these design principles, we proposed an analysis framework: an instrument to analyze the design of group work scenarios implemented by educators. Basically, this framework enables verifying—for each design principle and according to the way the educator performs the design—whether the design does not meet, partially meets or fully meets the principle. The result of the analysis is a score that represents the level of adherence of the educator's design to each design principle.

Table 1 presents the design principles, with a brief description of them.

Table 2 presents a piece of the analysis framework.

As presented in Table 2, for each design principle, three alternatives were specified (a, b and c)—for each one, a valuation score was defined: 0 (does not meet the principle), 0.5 (partially meets the principle) and 1 (fully meets the principle). Thus, according to the way the educator performs the design related to each principle, he/she gets a score. Considering all the principles, the educator can achieve a total score between 0 and 12.

Using this analysis framework, we carried out a case study in order to analyze the level of adherence to the 12 design principles of the (group work) design often performed by (a sample of) educators. Personal and semi-structured interviews were conducted with 30 professors from the computer science department of a Brazilian public university. Of these 30 professors, 27 had a doctor's degree and 3 had a master's degree. Regarding teaching experience in higher education (in years), 6 professors had less than 5 years, 7 had between 5 and 10, 13 had between 11 and 20, 2 had between 21 and 30, and 2 had more than 31 years. On average, the sample had 13 years of teaching experience. The sample was selected based on an intentional and non-probabilistic approach. As previously mentioned, we restricted this study to face-to-face computing higher education domain. This restriction was necessary due to the specificities of different knowledge areas, which naturally guide the teaching activity. As limitations of the study, we highlight the restricted scope, the strategy adopted for the selection of the sample and the number of participants. In addition, considering the data collection protocol, self-reported data by the participants may contain sources of bias.

The interview was divided into five phases—each one related to an aspect of the group work design domain. The objective of phase "a" was to investigate if the educators use group work practices when teaching undergraduate courses. Phase "b" aimed to obtain information about group formation strategy in CL scenarios proposed by them. Phase "c" aimed to analyze how these educators structure and specify the tasks of the group work (e.g., how granular they are specified, if their learning objectives are defined and if they are monitored during their development). In phase "d", the idea was to analyze how educators perform the evaluation of learners. Finally, phase "e" had the objective of verifying the understanding of the educators regarding the concept

Table 1 Design principles

Design principles	Description
1—Learning objective (work)	Its specification is recommended at the level of work activities, so that the learners are given the opportunity to better manage their achievement. Moreover, it is possible for the educator to carry out evaluation and monitoring processes in a more precise way and to have a clearer perception about the specific purposes of these activities and the concepts to be explored
2—Learning objective (learner)	Its specification for the learners (individually) is recommended, so that it enables the educator to monitor and evaluate the learning of each learner in a more precise way
3—group formation	The active participation of the educator is recommended in order to avoid inappropriate composition of groups
4—Activity Specification	It is recommended that they are defined with a high level of granularity (i.e., more specific activities) to facilitate the specification of their parameters (objectives, deadlines, etc.) and to enable educators to perform evaluation and monitoring processes more accurately
5—activity suitability	It is recommended that they are designed considering the learners' characteristics (instructional needs, level of knowledge, etc.) individually
6—activity division	The active participation of the educator is recommended in order to prevent the process from occurring improperly (i.e., students being responsible only for activities they consider easier for them) or unequally (i.e., few members being responsible for most tasks)
7—collaboration	It is recommended that it is fostered and also guided by the educator
8—monitoring (work development)	It is recommended that it is carried out at the activity level – thus, making it possible to obtain more precise information that is essential to the management of the process
9—monitoring (learning process)	It is recommended that it is done through careful observation. It is necessary to previously define goals, criteria and points of analysis. In addition, it should be done at the level of the students, so that the teacher is clear about the individual evolution of each student throughout the instructional process
10—activity guidance	It is recommended that the educator supports and guides learners in the accomplishment of the work activities
11—support material	It is recommended to provide materials that assist students in the development of each task
12—learning evaluation	It is recommended that it is carried out at the student level (individually) and throughout the work development

Table 2 Piece of the analysis framework

8 – Monitoring (work development)		
a	The educator does not monitor the development of the activities	0
b	The educator monitors the development of the activities through abstract elements; the monitoring process is carried out at the level of the work, its phases or activities (individually)	0.5
	The educator monitors the development of the activities through formal elements; the monitoring process is carried out at the level of the work	
c	The educator monitors the development of the activities through formal elements; the monitoring process is carried out at the level of the work phases or its activities (individually)	1
9 – Monitoring (learning)		
a	The educator does not monitor the learning process	0
b	The educator monitors the learning process through abstract elements; the monitoring process is carried out at the level of the class, groups or learners (individually)	0.5
	The educator monitors the learning process through formal elements; the monitoring process is carried out at the level of the class or groups	
c	The educator monitors the learning process through formal elements; the monitoring process is carried out at the level of the learners (individually)	1
12 – Learning evaluation		
a	The educator evaluates learners' learning through abstract elements; the educator evaluates the class, group or learners (individually); the process occurs only at the end of the work development	0
b	The educator evaluates learners' learning through formal elements; the educator evaluates the class, group or learners (individually); the process occurs during the work development	0.5
c	The educator evaluates learners' learning through formal elements; the educator evaluates the learners (individually); the process occurs during the work development	1

of collaboration and how they stimulate it within the group work scenarios. Through the analysis of the educators' answers, and using the analysis framework, the results of the case study are as presented in Table 3, in descending order regarding the level of adherence. The educators' level of adherence was defined based on their total score. The classification grades were: Null (0), Insufficient ($0 < \text{score} \leq 4$), Regular ($4 < \text{score} \leq 8$), Good ($8 < \text{score} \leq 12$) and Excellent (12).

Of the sample of 30 educators, 22 make use of group work practices while teaching undergraduate courses, 5 have already used it (but no longer use it), and 3 have never used it. For these 3, the interview ended after phase "a"—since our focus was on educators who make use of group work practices. Of those 5 educators, only 3 (marked in red in Table 3) decided to participate in the rest of the interview. For the other 2 educators, the interview ended after phase "a". Thus, the results presented in Table 3 refer only to those 25 educators.

These results show that, of the 25 educators, 21, 3 and 1 implement a design whose adherence level is, respectively, insufficient, regular and null. The results expose a set of deficiencies regarding the design of group work scenarios implemented by these 25 educators. In fact, they do not specify several of the important elements of the design process. We found that many educators do not specify such elements because they are not aware of them or simply because they do not know how to do it properly. Therefore, these results reinforce the necessity of providing educators with proper support and guidance when designing CL scenarios, helping them to both understand and specify the design elements.

CL Scenarios Design Infrastructure

Considering that the proposal of this study is to guide and support educators to appropriately design CL scenarios, the solution consists of a design infrastructure—which is composed of (a) a design metamodel and (b) a computational tool. The first one refers to a conceptual structure that conceptualizes the domain of CL scenarios design, and it is based on the 12 design principles mentioned in Sect. 2.1. The second one consists of a computational tool to support educators throughout the design process. Basically, the design workflow consists of specifying the elements/parameters of the metamodel, according to the educator's instructional intentions, generating a particular CL scenario that expresses them.

Figure 1 presents the design metamodel.

The proposed design metamodel is composed of 14 concepts. The basic structure of a project (group work) comprises the concepts Project, Section, Practice and Module. A Project is composed of Modules (topics explored in the project) and Sections. Learners/Groups perform Practices (development of learning activities) distributed through Sections. Practices can be sequenced and related to each other by the educator through an activity structure.

Table 3 Adherence to the design principles

	Design principles													
	1	2	3	4	5	6	7	8	9	10	11	12		
P3	0.5	0.5	0	0	0	0	0.5	0.5	0	0.5	1.0	1.0	4.5	Regular
P6	1	0.5	0	1	0	0	0.5	0	0	0	0.5	1.0	4.5	
P13	0.5	0.5	0	0.5	0.5	0	0.5	0.5	0.5	0.5	0.5	0	4.5	
P2	0.5	0.5	0	0.5	0	0	0	0.5	0.5	0.5	0.5	0	3.5	Insufficient
P4	0.5	0.5	0	0	0	0	0.5	0.5	0	0.5	1.0	0	3.5	
P11	0.5	0.5	0	0	0	0.5	0.5	0.5	0	0.5	0.5	0	3.5	
P5	0.5	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0	3	
P17	0.5	0.5	0	0.5	0	0	0	0.5	0.5	0.5	0	0	3	
P1	0.5	0.5	0	0	0	0	0	0.5	0	0.5	0.5	0	2.5	
P9	0.5	0.5	0	0	0.5	0	0	0	0.5	0	0.5	0	2.5	
P12	0	0	0	0.5	0	0	0.5	0.5	0	0	1.0	0	2.5	
P15	0.5	0.5	0	0.5	0	0	0.5	0.5	0	0	0	0	2.5	
P16	0.5	0.5	0	0.5	0	0	0	0.5	0	0	0.5	0	2.5	
P20	0.5	0.5	0	0.5	0	0	0	0.5	0	0.5	0	0	2.5	
P14	0.5	0.5	0	0	0	0	0	0	0.5	0	0.5	0	2	
P21	0.5	0.5	0	0	0	0	0	0.5	0	0.5	0	0	2	
P18	0.5	0.5	0	0	0	0	0.5	0	0	0	0	0	1.5	
P24	0	0.5	0	0	0	0	0	0.5	0	0.5	0	0	1.5	
P7	0	0	0	0	0	0	0	0.5	0	0.5	0	0	1	
P8	0	0	0	0	0	0	0	0.5	0	0	0	0.5	1	
P10	0	0	0	0	0	0	0	0.5	0	0.5	0	0	1	
P19	0	0	0	0	0.5	0	0.5	0	0	0	0	0	1	
P23	0	0	0	1	0	0	0	0	0	0	0	0	1	
P25	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	
P22	0	0	0	0	0	0	0	0	0	0	0	0	0	Null

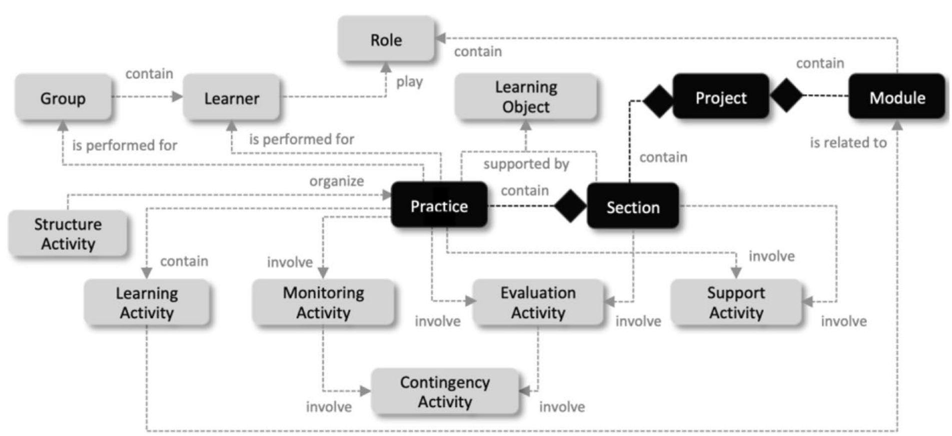


Fig. 1 Design metamodel

Learners can play roles in the Project. Learning objects can be used to support the development of Practices. Monitoring activities can be specified to monitor Practices or Sections. Evaluation Activities can be used to assess Practices or Sections. Educators can assist the development of Practices or Sections through a support activity. Contingency activities correspond to actions to be performed as a result of a specific condition identified by the educator through a monitoring or evaluation activity.

All the concepts comprise parameters that enable the educator to specify a particular aspect of group work design domain, according to the design principles. The learning objective (Project) principle, for instance, could be met through the specification of the parameters in the metamodel concepts Project, Section and learning activity. These concepts enable the educator to define, for instance, the general objective of the work, the objective of its sections and the objectives of each learning activity. In addition, it is possible, through the Project concept, to specify parameters such as identifier, description, and prerequisites.

The computational tool aims to provide support for the use of the design metamodel, guiding educators with regard to the analysis and specification of its elements. The development of the tool was carried out to support educators in specifying the 12 design principles. The tool provides a set of functionalities, grouped in six categories: **Create** (to create/register elements in a project; e.g., "create learning activity"), **Edit** (to complement/modify information of elements registered in the project; e.g., "edit practice"), **Visualize** (to visualize information of elements registered in a project or relationships between elements; e.g., "visualize learners assigned to practice"), **Include** (class of actions that enables the educator to relate elements; e.g., "include learning object in the section"), **Assign** (relate elements of a project; e.g., "assign role to learner"), **Delete** (class of actions that enables the educator to delete elements of the project or "disconnect" related elements; e.g., "delete monitoring activity of the section"). The development of the tool was carried out based on the Object Oriented Programming paradigm and PHP programming language. It was structured as a monolithic Web application, using a multilayer architecture.

Figure 2 presents one of the tool's screens.

In Fig. 2, marking A highlights the administration menu, which enables, for example, to access the educator's projects. Marking B highlights the design menu, which enables the educator to carry out a planning process. Marking C shows the form for registering the basic information about a project. Marking "D highlights the information and guidelines for specifying each of the form fields. The tool contains several processes related to specifying the various design parameters. It controls all these processes, performing all the necessary analyses. Thus, the educators are only responsible for decision-making and also for registering, through the forms, information regarding all aspects of the project.

Design Infrastructure 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 educators in conducting the learning process or if it promotes learners' learning. Actually, the goal was twofold: (a) to analyze the educators' perception about the guidance and support provided by the infrastructure and (b) to analyze the level of adherence of the design implemented by them, through its use, to the 12 design principles. Although it is relevant to analyze the effectiveness of the design in supporting educators in conducting learning processes, as well as in fostering

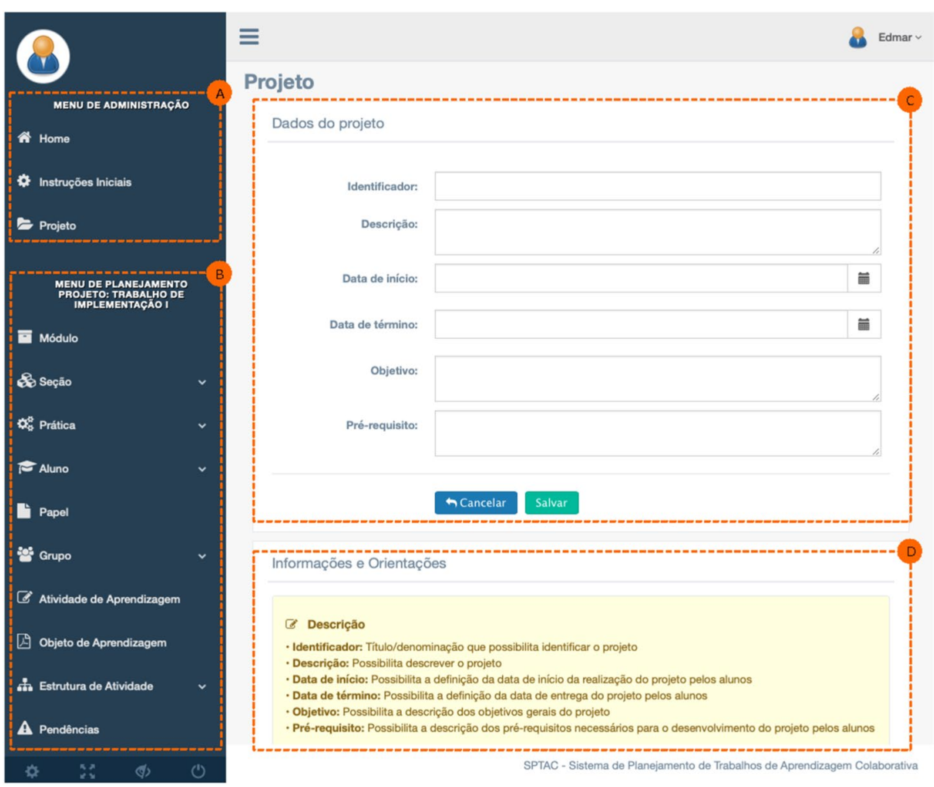


Fig. 2 Project specification screen

the development of learners' learning, these are issues to be addressed in future works.

As mentioned in Sect. 1, this study adopted the case study research methodology, with a qualitative and exploratory approach [20]. Our hypothesis was that the proposed infrastructure provides educators with support and guidance when designing CL scenarios, helping them to both understand the important design parameters and to specify them. The case study was carried out throughout one semester in a university, with educators in real situations of group work design. 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, enabling a broad view of the studied phenomenon. The definition of the cases, as well as of the units of analysis (educators), was based on the results from our previous study [17]—discussed in Sect. 2.1.

The definition of the cases was based on the following three criteria: (a) interest in using group work practices, (b) use of group work practices and (c) the level of adherence of the design to the design principles. As a result, four cases were defined—as presented in Fig. 3. Particularly, the case study did not consider the group of educators, who, in our previous study, reported not using group work practices or not having any interest in this learning approach.

The selection of the units of analysis was based on the scores (level of adherence to the design principles) presented in Table 3, and also on the educator's interest and availability to participate in the study. For cases 2 and 4, our interest was to select the educators with the lowest and highest levels, respectively. For case 3, the interest was to select educators with different levels. Three units of analysis were selected for each case; this was based on Yin [20]—according to him, in multiple case study projects, it is necessary to have at least two units in each case. Table 4 presents the selected units. On average, this sample had 11 years of teaching experience

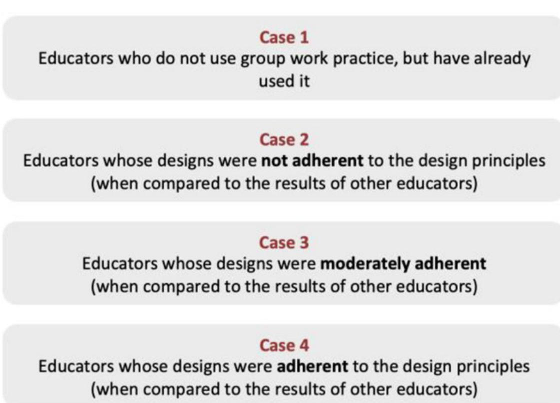


Fig. 3 Cases of the case study

Table 4 Units of analysis of the case study

Cases	Selected educators	Adherence level
1	P23	1
	P24	1.5
	P25	0.5
2	P18	1.5
	P19	1
	P22	0
3	P14	2
	P16	2.5
	P20	2.5
4	P2	3.5
	P6	4.5
	P17	3

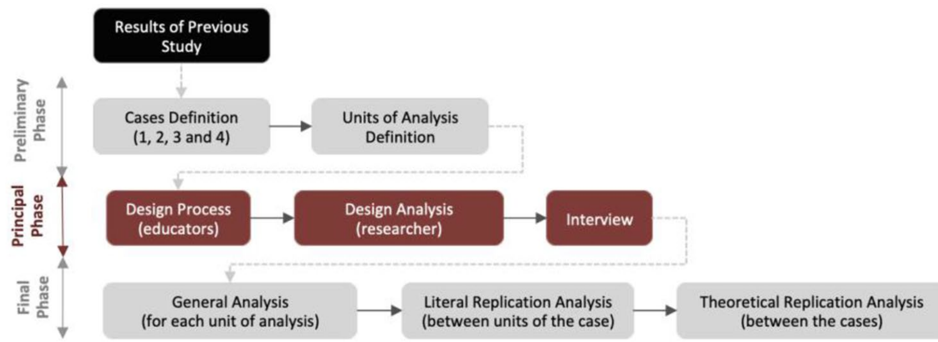
in computing higher education, with 11 educators having a doctor's degree and 1 having a master's degree.

The data collection protocol is presented in Fig. 4.

This data collection protocol comprises three phases: preliminary phase, principal phase and final phase, with specific phases in each one. In the first one, the cases and the units of analysis of the case study were defined. The principal phase comprised the phases of design, analysis and interview. In the design phase, the educators carried out, through the proposed infrastructure, the design of a group work practice. All educators had approximately 6 weeks to complete the design. The case study started at the beginning of the academic semester of a university. At the end of this phase, the researchers performed an analysis of the design carried out by each educator to evaluate its adherence to the 12 design principles. The same analysis framework specified in our previous study was adopted—thus, with the educators getting, for each design principle, a score 0, 0.5 or 1 depending on whether their design does not meet, partially meets or fully meets the principle.

The interview phase consisted of personal and semi-structured interviews with each educator. The goal was to analyze the educators' perception about the use of the infrastructure. Specifically, we aimed to analyze if the infrastructure guided and supported them throughout the design process and also if it helped them in understanding the design principles (both in terms of their specification and the relevance of carrying out a design that contemplates them). The final phase comprised the analysis phases of the case study: general, literal replication and theoretical replication. The first one intended to analyze each educator individually. The literal replication intended to compare, for each case, the educators to each other, based on the results of the general analysis—thus, making it possible to obtain the conclusions for each studied case. The theoretical replication analysis intended to

Fig. 4 Data collection protocol of the case study



compare the cases to each other, based on the results of the literal analysis—thus, making it possible to obtain a broad view of the phenomenon studied. These analysis phases were performed according to Yin [20].

Results and Discussion

As previously mentioned, the case study intended to analyze (a) the level of adherence of the design carried out by the educators (through the proposed design infrastructure) to the 12 design principles, and (b) their perception regarding the guidance and support provided by the infrastructure. Regarding item “a”, the design often carried out by the educator (Table 3) was compared with that carried out through the infrastructure. Table 5 presents, for each case and each educator, the level of adherence obtained without using the infrastructure (WI) and using it (UI).

These results show that all educators, of cases 1, 2, 3 and 4, achieved a higher level of adherence—when comparing the scores related to the design without using the infrastructure and using it. Therefore, the infrastructure was able to support all educators in carrying out a CL design more adherent to the design principles. Besides, for all cases, a significant improvement in terms of adherence to the design principle was observed, when comparing the scores of the educators without using the infrastructure and using it. For case 1, the sum of the scores of educators P23, P24 and P25 increased from 3 to 17. For cases 2, 3 and 4, this total score—to their respective educators—increased from 2.5 to 18.5, from 7 to 19.5 and from 10.5 to 19.5, respectively. These results show that the infrastructure had a greater impact in cases 2 and 1, and less impact in cases 4 and 3, respectively, cases with the lowest and the greatest level of adherence without the infrastructure. Therefore, in the cases in which the educators presented more expressive difficulties in terms of design (without the infrastructure), the infrastructure provided greater support capability in helping them 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 was the support capability provided to them by the infrastructure.

When analyzing the scores using the infrastructure, it is possible to notice that there was no significant difference between most educators. The results, therefore, show that the infrastructure was able to uniform the level of adherence between them—this means that the educators with more significant difficulties in carrying out a design adherent to the principles were able to achieve a similar level to those with less difficulty.

Regarding item “b”, as previously mentioned, the purpose was to analyze the support and guidance provided by the infrastructure and if it helped the educators in understanding the specification of the design principles and the relevance

Table 5 Adherence level comparison analysis

	Case 1			Case 2			Case 3			Case 4		
	P23	P24	P25	P18	P19	P22	P14	P16	P20	P2	P6	P17
WI	1	1.5	0.5	1.5	1	0	2	2.5	2.5	3.5	4.5	3
UI	5	8	4	8	5	5.5	5.5	7.5	6.5	7	6	6.5
	Total score (per educator)											
WI	3			2.5			7			10.5		
	Total score per case (sum of teachers' grades – per case)											
UI	17			18.5			19.5			19.5		
	Total score per case (sum of teachers' grades – per case)											

of carrying out a design that contemplates them. The results were obtained from the interviews carried out in the interview phase (Fig. 4). Figure 5 presents some of the issues investigated through the interview.

Regarding question 1, all educators emphasized the relevant contribution of the infrastructure. Some of them stated that they had never thought of carrying out a design considering all the design principles. Other educators mentioned considering some of the principles, but in an intuitive/abstract way and not formally specified as it is proposed by the infrastructure. In this context, they affirmed that the infrastructure helped them in designing the group work scenario and in the process of thinking about it. Regarding question 2, all educators mentioned the significant support and guidance provided by the infrastructure, emphasizing that the processes were well linked, described and also explained. Some of them affirmed that the infrastructure guided them on which parameters should be specified and how. Other educators mentioned the learning provided by the infrastructure, in the sense that it encourages thinking about the scenario in a more effective way.

Regarding question 3, all educators answered positively, emphasizing that the principles are important for both learners (helping them throughout the learning process) and educators (helping them to conduct the learning process). Some of them affirmed they thought they were doing a proper design, but realized they had to think about elements they usually do not. For question 4, all educators also answered positively. They mentioned that, after using the infrastructure, they had another view of how to design group work scenarios. Regarding question 5 (only for the educators of case 1), the three educators affirmed that the infrastructure, to some degree, encourages the use of CL practices. According to them, it provides proper support and guidance throughout the process—significantly reducing the complexity involved.

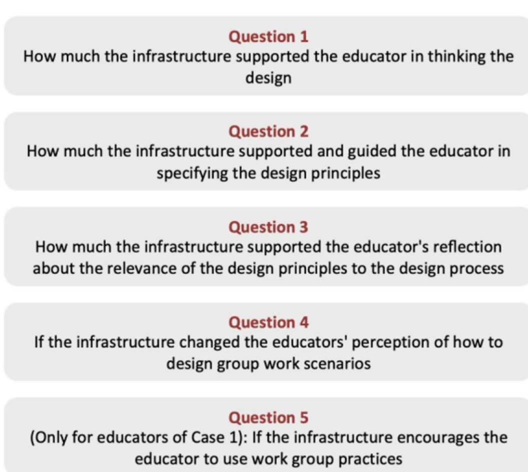


Fig. 5 Investigated issues

In addition, it impels the educator to think about various aspects of design. Of the three educators, two mentioned that it naturally provides a more laborious process—according to them, a possible point of discouragement.

In addition to the previously mentioned questions, the interview also aimed to verify the educators' perception regarding each design principle. When evaluating a design principle as positive (+), the educator considers that thinking about it was interesting, that it was relevant to the design process and that the infrastructure helped him/her in its analysis. When evaluating a design principle as negative (–), the educator considers it confusing/complex (the educator did not understand it) or even harmful to the learning process. When evaluating a design principle as indifferent (=), the educator considers that it is not interesting (i.e., it is not aligned with the way he/she usually designs group works), or it does not have significant advantages (e.g., it is already considered when designing group work scenarios). Table 6 presents the educators' perception regarding all the 12 design principles.

These results showed that all design principles were positively evaluated. Only three principles were negatively evaluated for one educator. According to him, it was complex to think about some design principles (in his opinion, perhaps because of lack of practice, i.e., he is not used to thinking about them). The principles 3 and 6 were most rated as indifferent. In the interviews, both of them were frequently mentioned as a strategy not aligned with the way the educators usually design their group work scenarios. The educators, therefore, affirmed they prefer to leave both the formation of groups and the division of work activities under the learners' responsibility. Particularly, this result highlights some educators' resistance to change some aspects of their perception of how to design group work scenarios. However, even for these educators, the design principles are relevant.

In this study, the proposed solution was to provide an infrastructure able to support and guide the educators throughout the design of group work scenarios. Particularly, it was intended (a) to make explicit to these educators relevant design parameters and (b) to help them in their specification, consequently, improving the level of adherence to the design principles and helping the educators in understanding them. The infrastructure, as shown through the results, supported and guided the educators in carrying out a design more adherent to the design principles and also helped them in understanding these principles.

Conclusions

Careful planning is essential for the effectiveness of CL scenarios. However, the design of such scenarios is a complex task, and many of the important parameters inherent to the

Table 6 Educators' perception regarding the design principles

		Design principles											
		1	2	3	4	5	6	7	8	9	10	11	12
1	P23	+	+	=	+	+	+	+	+	+	+	+	+
	P24	+	+	+	+	+	+	+	+	+	+	+	+
	P25	+	−	+	+	−	=	=	+	−	+	+	+
2	P18	+	+	+	+	+	=	+	+	+	+	+	+
	P19	+	=	=	=	=	=	=	+	+	=	=	+
	P22	+	+	=	+	+	+	=	+	+	+	+	+
3	P14	+	=	+	+	=	=	+	+	=	=	+	+
	P16	+	+	+	+	+	+	+	+	+	+	+	+
	P20	+	+	+	+	+	=	+	+	+	+	+	+
4	P2	+	+	=	+	+	=	+	+	+	=	=	+
	P6	+	=	=	=	=	=	+	+	=	=	=	=
	P17	+	+	=	+	=	=	+	+	+	+	+	+

process are not taken into account and/or specified by the educators. Consequently, they are usually inappropriately and inefficiently structured, making it difficult for the learners to achieve the learning objectives. In this context, it is crucial to provide educators with proper support and guidance, exposing them to parameters and processes that should be accounted for in the CL scenarios' design process.

Our previous study highlighted a set of deficiencies regarding the design of group work scenarios carried out by a set of educators, showing that many of them do not specify important parameters because they are not aware of them or simply because they do not know how to do it properly. Based on these results, this study proposed a computational infrastructure able to guide and support educators throughout the process of designing CL scenarios. It was carried out under the case study methodology, with a sample of educators in real situations of group work design. As a hypothesis, it was assumed that the infrastructure provides these educators with support and guidance when designing CL scenarios, exposing them to relevant design parameters, supporting them in their specification and helping them to understand these parameters.

The results showed that, unlike current approaches and tools, the infrastructure proposed in this study provides both flexibility and support/guidance to educators. In fact, it not only helps educators in specifying relevant elements inherent to the CL scenarios' design process (covering different aspects of collaborative practice), but also helps them to assimilate these elements. Furthermore, the educators are totally free to decide how and which elements should be specified—thus, they could structure a CL scenario according to their needs and intentions. As future works, our intention is to investigate the impact of the proposed design infrastructure on learners' learning. We also aim to carry out computational improvements on it, as well as the conceptual structure that supports it.

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Code Availability Not applicable.

Declarations

Conflicts of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Kimble C, Hildreth P, Bourdon I. Communities of practice: creating learning environments for educators, vol. 1. Charlotte, NC: Information Age Pub; 2008.
2. Dillenbourg P, Baker M, Blaye A, O'Malley C. The evolution of research on collaborative learning. In: Spada E, Reiman P, editors. Learning in humans and machine: Towards an interdisciplinary learning science. Oxford: Elsevier; 1996. p. 189–211.
3. Isotani S, Mizoguchi R, Isotani S, Capeli OM, Isotani N, Albuquerque AR, Jaques P. A Semantic Web-based authoring tool to facilitate the planning of collaborative learning scenarios compliant with learning theories. Comput Educ. 2013;63:267–84.
4. Isotani S, Mizoguchi R, Inaba A, Ikeda M. The foundations of a theory- aware authoring tool for CSCL design. Comput Educ. 2010;54:809–34.
5. Dillenbourg P. Over-scripting CSCL: The risks of blending collaborative learning with instructional design. Three worlds of CSCL. Can we support CSCL? https://telearn.archives-ouvertes.fr/hal-00190230. Accessed 25 Sept 2021
6. Strijbos JW, Martens RL, Jochems WMG. Designing group based learning: six steps to designing computer-supported group based learning. Comput Educ. 2004;42:403–24.
7. King A. Scripting collaborative learning processes: a cognitive perspective. In: Fischer F, Kollar I, Mandl H, Haake JM, editors. Scripting computer-supported collaborative learning. Computer-supported collaborative learning, vol. 6. Boston, MA: Springer; 2007. p. 13–37.

8. Battou A, Baz O, Mammass D. Toward a virtual learning environment based on agile learner-centered design. Intell Syst Comput Vis. 2000. https://doi.org/10.1109/ICMCS.2016.7905666.
9. Kaendler C, Wiedmann M, Rummel N. Teacher competencies for the implementation of collaborative learning in the classroom: a framework and research review. Educ Psychol Rev. 2015;27:505–36. https://doi.org/10.1007/s10648-014-9288-9.
10. Bennett S, Agostinho S, Lockyer L. Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices. Comput Educ. 2015;81:211–20. https://doi.org/10.1007/s10648-014-9288-9.
11. Barkley EF, Major CHK, Cross KP. Collaborative learning techniques: A handbook for college faculty. 2nd ed. San Francisco: Jossey-Bass; 2014.
12. Höver KM, Mühlhäuser M. Can We Use S-BPM for Modeling Collaboration Scripts? In: Zehbold C, editor. S-BPM ONE - Application Studies and Work in Progress; 2014. https://doi.org/10.1007/978-3-319-06191-7_13
13. Clement M, Vandeput L, Osaer T. Blended learning design: a shared experience. Procedia: Soc Behav Sci. 2016;228:582–6. https://doi.org/10.1016/j.sbspro.2016.07.089.
14. Ruys I, Keer VH, Aelterman A. Student teachers' skills in the implementation of collaborative learning: a multilevel approach. Teach Teach Educ. 2011;27:1090–100. https://doi.org/10.1016/j.tate.2011.05.005.
15. Gillies RM, Boyle M. Teachers' reflections on cooperative learning: issues of implementation. Teach Teach Educ. 2010;26:933–40. https://doi.org/10.1016/j.tate.2009.10.034.
16. Chikh A. A general model of learning design objects. J King Saud Univ Comput Inf Sci. 2014;26:29–40. https://doi.org/10.1016/j.jksuci.2013.03.001.
17. Oliveira EW, Borges MRS. How educators design group learning scenarios in higher education? In: International Conference on Information Technology Based Higher Education and Training; 2019. https://doi.org/10.1109/ITHET46829.2019.8937375
18. Prieto LP, Asensio-Pérez JI, Muñoz-Cristóbal JA, Dimitriadis YA, Jorrín-Abellán IM, Gómez-Sánchez E. Enabling teachers to deploy CSCL designs across distributed learning environments. IEEE Trans Learn Technol. 2013;6:324–36. https://doi.org/10.1109/TLT.2013.22.
19. Oliveira EW, Borges MRS. Supporting educators to design collaborative learning scenarios. In: International Conference on Computer Supported Education; 2021. https://doi.org/10.5220/0010458700950103
20. Yin RK. Case study research design and methods. 5th ed. Thousand Oaks, CA: Sage; 2014.
21. O'Donnel AM, Dansereau D. Scripted cooperation in student dyads: a method for analyzing and enhancing academic learning and performance. In: Hertz-Lazarowitz R, Miller N, editors. Interaction in cooperative groups: the theoretical anatomy of group learning. Cambridge: Cambridge University Press; 1992. p. 120–41.
22. Hernández-Leo D, Villasclaras-Fernández ED, Asensio-Pérez JI, Dimitriadis Y, Jorrín-Abellán IM, Ruiz-Requies I, Rubia-Avi B. COLLAGE: A collaborative Learning Design editor based on patterns. Educ Technol Soc. 2006;9:58–71.
23. Jonassen DH, Tessmer M, Hannum WH. Task analysis methods for instructional design. 1st ed. Mahwah: Lawrence Erlbaum Associates; 1999.
24. Challco GC, Bittencourt II, Isotani S. Computer-based systems for automating instructional design of collaborative learning scenarios: a systematic literature review. Int J Knowl Learn. 2016. https://doi.org/10.1504/IJKL.2016.084745.

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