LEARNING DESIGN FOR COLLABORATIVE COURSES IN MATHEMATICS EDUCATION: INTEGRATING DYNAMIC MATHEMATICS SYSTEMS WITHIN LEARNING ACTIVITY MANAGEMENT SYSTEMS

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Abstract: *This study emphasizes the role of integrating Dynamic Mathematics Systems (DMS) within the context of learning design based systems for the design of appropriate collaborative blended courses in mathematics education. To this end, a learning environment was formed using an integration of the following well known two pieces of free open source software (FOSS), namely: (a) the Geogebra (www.geogebra.org), DMS environment and (b) the Learning Activity Management System (LAMS; [1]). In fact, this study suggests that integration of FOSS such as LAMS and Geogebra -at the same time promoting collaboration among students using specific design patterns- could provide a fruitful environment for the learning of various mathematical concepts. To clarify the features of this learning environment, a specific example regarding with the design of a sequence of collaborative learning activities for the learning of the geometrical concept of angle is presented.*

Keywords*: e-learning, learning design, mathematics education, Geogebra, LAMS*

1. INTRODUCTION

The description of the teaching-learning process that takes place in a unit of learning has been defined as a 'learning design' [2]. A unit of learning, can be characterized a course, a lesson or any other learning event, such as a specific collaboration structure. The key principle in 'learning design' is that it represents the learning activities that need to be performed by learners and teachers within the context of a unit of learning. An essential part of a 'learning design' is that pedagogy is conceptually abstracted from context and content, so that excellent pedagogical models can be shared and reused across instructional contexts and subject domains. In fact, such pedagogical models can be reflected in the formation of specific '*design patterns'* which are context free and could be shared and reused across various instructional contexts and essentially assist online learning.

Research in e-learning also shows that involving learners in online collaborative learning activities could provide them with essential opportunities to: enhance their diversity in terms of the learning concepts in question [3], extend and deepen their learning experiences, try new ideas and improve their learning outcomes [4], trigger their cognitive processes [5], motivate active engagement in their learning [6], and interact socially, developing a sense of community and belonging online [7]. In the context of "learning design', the role of collaborative design patterns is to indicate clearly the flow of collaboration activities using specific collaboration structures. Although, computer-supported collaborative learning has been recognized as an emerging paradigm of educational technology [8], many teachers remain unsure of why, when, and how to integrate collaboration into their teaching practices in general, let alone their online classes [9]. It seems clear; that teachers need high level tools to understand learning design and it is likely that tools specialized for a particular pedagogic context will be easier to use [10]. To this end, it is worth noting that the type of editor that classroom teachers usually need should be similar to authoring environment provided by LAMS, a well-known integrated e-learning system that effectively supports the idea of ‘learning design’. Recently, a number of collaboration design patterns have been constructed using the tools provided by LAMS [11-12].

Especially when it comes to Mathematics Education, there are also various valuable pieces of educational software that can be used by the teachers for the design of learning activities that can encourage student learning according to modern social and constructivist views of knowledge construction [13-14]. To this end, Geogebra is a piece of software that is also open source and can support the learning of various Mathematical concepts in a dynamic way that is well situated in the context of the aforementioned modern views of knowledge construction. Despite the above, mathematics educators encounter various difficulties in adopting innovating approaches to ‘learning design’ in general [15-16] and in ‘collaborative learning design’ in particular [17] as well as in integrating of essential pieces of educational software in their real classroom practices [18]. It seems that, mathematics teachers require more specific support in their learning design practices, such as specific tools and good examples of learning activities. Thus, mathematics teacher encouragement and support for learning design is clearly needed.

Taking into account all the above, we have attempted to form a collaborative learning environment by integrating FOSS such as Geogebra and LAMS with the ‘Jigsaw’ collaborative method [19] to construct a sequence of learning activities for an intra-disciplinary understanding of the mathematical notion of angle. Such an environment for the learning of mathematical concepts - using the Jigsaw method within LAMS and Geogebra- has not yet been reported. In the following section of this paper, the essential features of LAMS and Geogebra are briefly presented and followed by a description of the Jigsaw collaboration method. Then, a specific example of using Jigsaw-within-LAMS and Geogebra for the learning of the mathematical notion of angle is demonstrated. Finally, the design of this sequence is discussed and conclusions and future research plans are drawn.

2. A BRIEF DESCRIPTION OF GEOGEBRA, LAMS AND JIGSAW

Geogebra is a Dynamic Mathematics System that provides diverse tools to support the learning of a plethora of mathematical concepts included in Euclidian geometry, in analytic geometry and in algebra. These concepts can be also studied in integration. In addition, Geogebra provides tools to construct multiple representations, both numerical and visual, such as geometrical figures, tables, equations, graphs and calculations which can also be interlinked. To this end, there is also the possibility of collecting large amounts of numerical data which can be used by students to form and verify conjectures regarding the mathematical concepts in focus. Furthermore, the graphical constructions within Geogebra are dynamic that means they can be directly manipulated by using the ‘drag mode’ operation, thus conserving their basic properties while altering their form. Moreover, Geogebra is a highly interactive environment that also provides learners with multiple types of information (text, figures, numbers) and feedback (intrinsic visual and extrinsic numerical) to facilitate the formation and verification of conjectures as well as self-correction of their constructions. Finally, possibilities for the extension of the environment are also available to teachers and learners through the addition of specific macros on the Geogebra -interface. All these aforementioned capabilities can encourage constructivist, exploratory learning, experimentation, self control, reflection, as well as formation, testing and reformulation of hypotheses.

LAMS is an open source e-learning system that emphasizes the design of learning activities rather than the delivery of learning content. LAMS, also provides teachers with strong capabilities to design sequences of learning events that could be delivered to the students through face-to-face, online and blended courses. In fact, LAMS is a revolutionary learning environment that supports learning design as it provides teachers with great opportunities in terms of: (a) easy and intuitive design of sequences of learning activities even for those who do have not any programming experience and knowledge [20], (b) the ability to 'Preview' the sequences of learning activities through the lens of the learners [21], (c) possibilities to take a general overview of the entire sequence of learning activities on the computer screen [20], (d) possibilities for improvement of such a sequence even though it is running online in real-time, (e) possibilities for transforming a ready-made sequence of learning activities. Thus, the role of the teacher is not reduced to the role of a traditional behavioristic practitioner [22] who has to use 'learning designs' ready-made by expert learning designers, (f) possibilities of fine grained grouping and branching (g) possibilities for adapting the sequence of learning activities according to students' previous knowledge, preferences and specific learning styles using appropriately designed questionnaires in combination with grouping and branching , (h) provision with 'well working' learning design patterns – using the Activity Planner - that could be adapted by the teachers, (i) generic 'blank' learning sequences representing -as design patterns- 'well known' collaboration learning strategies [11-12] which are available by members of the LAMS community (see sequences uploaded by Kordaki, M. at http://www.lamscommunity.org/lamscentral/). To this end, the community of learners built around LAMS could play an encouraging role for the teachers and the designers of learning activities by providing them with opportunities to exchange experience and knowledge. However, LAMS has general characteristics and tools that make it appropriate for the design of learning activities dedicated for the learning of concepts of different domains of knowledge. To this end, a learning environment based on the integration of LAMS with Geogebra could become a fruitful context for the learning of various mathematical concepts.

The *Jigsaw* method was originally proposed by E. Aronson [19] at the University of Texas and the University of California. Jigsaw-based activities are used in hundreds classrooms with much success (see http://www.jigsaw.org). Jigsaw has been seen as a method that can support both cooperative and collaborative learning. Gallardo [23] also thought that this method could be well situated within the constructivist framework of learning. In addition, many researchers have proposed the implementation of this method within the online context [23, 12], despite the fact that Jigsaw was originally proposed for face-to-face education. Each member of the team has to excel in a well-defined subpart of the whole educational activity in question, undertaking the role of expert. The experts form a different group to discuss the nuances of the subject and later return to their teams to teach their colleagues. The ideal size of teams is 4 to 6 members. Specifically, the implementation of the Jigsaw method could be realized through the following process: (1) Divide the problem into sub-problems, (2) Create heterogeneous groups, (3) Assign roles and material to each student, (4) Form group of experts, (5) Let experts study the material and plan how to teach their colleagues, (6) Let experts teach in their groups, (7) Assess students. Using Jigsaw, the following goals could be achieved: (a) Building of interpersonal and interactive skills, (b) Ensuring that learning revolves around interaction with peers, (c) Holding students accountable among their peers, and (d) Encouraging active student participation in the learning process.

3. INTEG RATING GEOGEBRA AND JI GSAW WITHIN LAMS: AN E XAMPLE FOR THE LEARNING OF ANGLES

A central role in the development of geometric knowledge is played by the understanding of the concepts of angle and rotation [24]. However, students often encounter many difficulties in learning relevant aspects of these concepts [24]. Previous research makes it clear that students have great difficulty coordinating the various facets of the angle embedded in various physical angle contexts involving slopes, turns, intersections, corners, bends, directions and openings [25]. Angles have been defined in two ways: as a part of the plane included between two rays meeting at their endpoints (the static definition) and as the amount of rotation necessary to bring one of its rays to the other ray without moving out of the plane (the dynamic definition) [26]. To this end, the dynamic definition of angle introduces the concept of directionality. It is important for students to grasp both of these definitions so as to avoid various misconceptions. At this point, it is important to note that - when the emphasis is on the static definition - students confuse angle measure with area [27]. Students also typically believe that angle measures are influenced by the lengths of the intersecting lines or by the angle's orientation in space. Often children have little or no conception of angle as a measure of rotation. On the whole, students need to conceptualize the notion of angle as a movement, as in rotation or sweep; as a geometric shape, a delineation of space by two intersecting lines; and as a measure, a perspective that encompasses both of the previous. However, in the course of schooling, students also need to encounter multiple issues of the notion of angle, including [28]: (a) Angles of various kinds and sizes, © Angles created by lines in specific configurations (d) Angles inscribed in a circle, (e) Angles in triangles and quadrilaterals (e) Angles in polygons, and (f) Angles in congruent and similar shapes.

Here it is worth noting that, to help students successfully develop turn concepts and turn measurement, some approaches using LOGO have been reported, while other approaches have emphasized the use of concrete analogies as well as children's experience with physical rotations, especially rotations of their own bodies [24]. Despite this fact, the use of features of DMS -such as Geogebra- to provide students with opportunities to dynamically explore the aforementioned multiple issues of the notion of angle at the same time overcoming their difficulties and considering not only its static but also its dynamic character has not yet been reported.

The proposed Jigsaw online learning activity –within Geogebra and LAMS- consisted of the following seven phases: 1) Introduction to the activity, 2) Original group creation, 3) Creation of expert groups, 4) Back to the original groups, 5) Group Report formation, 6) Group Report presentation and 7) Assessment. The implementation of these phases within the context of LAMS is diagrammatically represented - as a 'design pattern' - in Figure 1. The presentation of this collaborative pattern aims at supporting a combination of synchronous and asynchronous collaboration but this pattern could be used exclusively for asynchronous collaboration by substituting the "Chat and Scribe" function with the "Forum and Scribe" function or vice versa to support exclusively synchronous collaboration. The description of the aforementioned phases is reported in the following section.

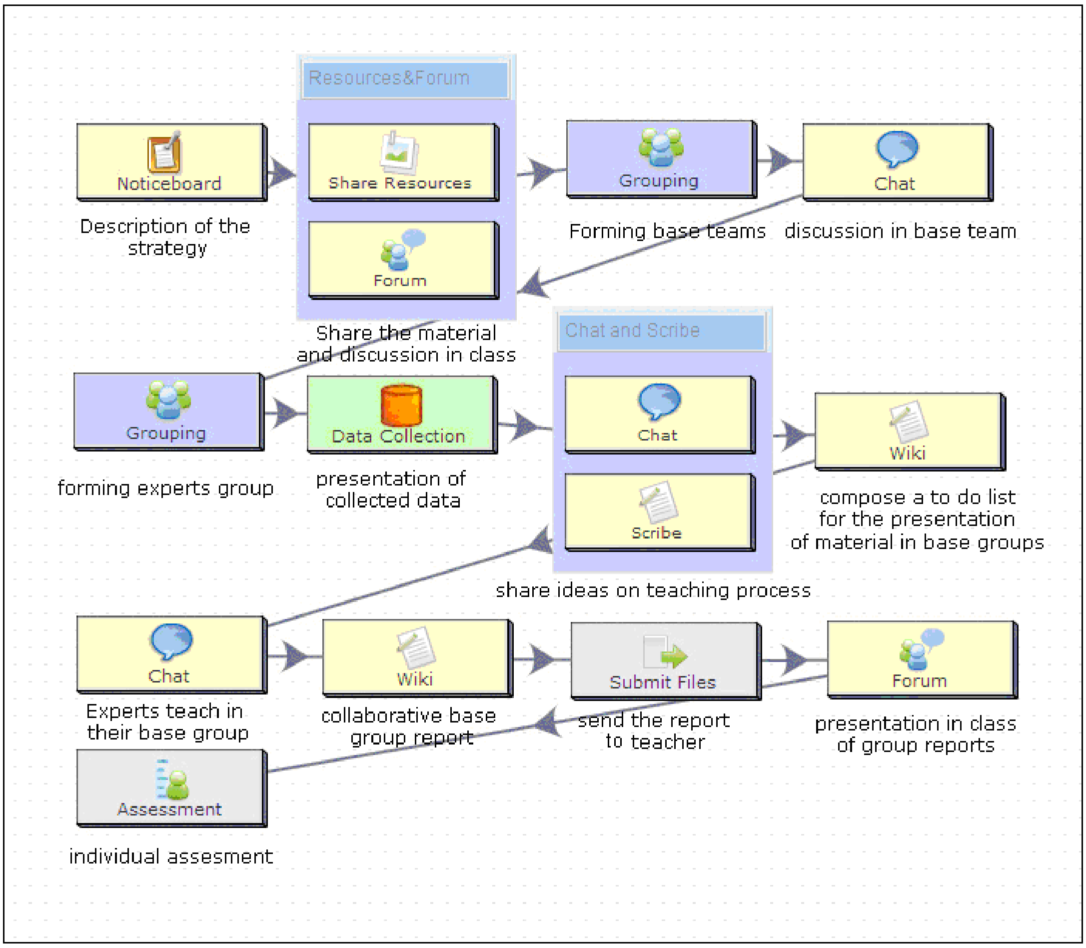

Fig. 1. A diagrammatic representation of the Jigsaw method implemented within LAMS

Phase 1: Jigsaw: *Introduction to the activity*

The main goal of this learning activity is to encourage students to conceptualize through performing specific investigations -within Geogebra based interactive constructions- the various issues of the mathematical notion of angle reported in the previous section. Additionally, this learning activity aims to highlight the value of collaborative learning as a modern method of teaching. To perform these investigations, students should be separated into expert groups according to the aforementioned issues. To this end, the following expert groups need to be formed: (a) the *Specific kinds of angles* Jigsaw Group (b) the *Angles and lines* Jigsaw Group (c) the *Angles and circle* Jigsaw Group (d) the *Angles in triangles and quadrilaterals* Jigsaw Group (e) the *Angles in polygons* Jigsaw Group and (f) the *Angles in congruent and similar shapes* Jigsaw Group.

To perform the aforementioned investigations successfully, each of the aforementioned groups have to experiment with specifically designed interactive constructions which have been realized using Geogebra and are integrated as remote labs within LAMS. In this phase of the Jigsaw activity, students are informed - using a Notice board - about the whole context of the activity, including its aims, the specific issues of the mathematical notion of angle that have to be addressed during this activity. In addition, students are informed about the possibility to use as specific virtual laboratories a number of interactive constructions implemented using Geogebra. These constructions should support students acquire appropriate experience so that to construct the necessary knowledge to fulfil the aims of the whole learning activity. Students should exchange ideas and clarify the aims and the whole procedure of the activity using a whole-class Forum or a whole class Chat-room.

Phase 2. Jigsaw: *Original group creation*

The students are assigned randomly – using the Grouping tool - to 4 groups of 6 students. Initially each group discusses – using a group chat-room or a group forum - the issues presented in the introduction, striving to form a commonly acceptable framework of ideas. Each member of each group should also decide which essential issue of the mathematical notion of angle they prefer to investigate.

Phase 3. Jigsaw: *Creation of expert groups*

Next, every member of each group would gain expertise on a specific issue of the proposed learning activity through their participation in specific expert-groups. Each expert group have to experiment with the provided e-Labs within Geogebra -mentioned in the 'Introduction' of the activity- to acquire experience, collect specific data and finally, form and test appropriate hypotheses about the issues of the notion of angle they undertook to study. In fact, each expert group has to fulfil a well-defined task, as it is described in the next section.

***Specific kinds of angles* Jigsaw Group**:

The experts in this group should investigate specific interactive constructions –using Geogebra- to clarify the properties of different kinds of angles such as: acute angles; right angles; obtuse angles; straight angles and reflex angles; as well as vertically opposite angles, complementary and supplementary angles.

***Angles and lines* Jigsaw Group:**

The experts in this group should experiment with appropriate interactive Geogebra-constructions to identify the appropriate estimation of the size and the relationships among the pairs of angles constructed when 2 parallel lines are intersected by another straight line. They can also clarify that perpendicular lines are at right angles while parallel lines never intersect to form an angle.

***Angles and circle* Jigsaw Group:**

The experts in this group could cope with Geogebra-constructions to explore those angles inscribed in a semicircle; the angles inscribed in arcs of the same but also of different size as well as angles inscribed and central angles of a circle in equal arcs and the relationships between their sizes.

***Angles in triangles and quadrilaterals* Jigsaw Group:**

The experts in this group have to experiment with specific Geogebra-constructions to investigate the kind of angles in various types of triangles (equilaterals, isosceles and scalene triangles) and quadrilaterals (squares, rectangles, parallelograms, rhombuses and spontaneous quadrilaterals) as well as the sum of the interior angles in any of these shapes.

***Angles in polygons* Jigsaw Group:**

The experts in this group should perform investigations using Geogebra-constructions in order to explore various issues regarding angles in regular/irregular polygons such as: size of angles, relationships among the number of sides and the size of angles in regular polygons as well as the sum of interior/exterior angles of a n-sided polygon.

***Angles in congruent and similar shapes* Jigsaw Group:**

The experts in this group should experiment with various Geogebra constructions realizing congruent and similar shapes to make it clear that: congruent shapes have identical corresponding angles (as well as equal corresponding sides) but the orientation of the shapes may be different while similar shapes have identical corresponding angles (but corresponding sides are only proportional in length and the orientation of the shapes may be different).

The data collected by each expert group should also be categorized using specific criteria and hypotheses they themselves have formed and those suggested by their teacher. Here, the use of the 'Data collection" tool will be useful. To this end, appropriate learning materials can be used for further understanding of the experimental activity of each expert group. Besides experimentation, data collection, processing and hypothesis formation about the various issues of the notion of angle, the expert groups have to organize an interesting and efficient teaching process to help their colleagues in base groups really construct knowledge about these issues. Sharing ideas about the appropriate teaching process could be implemented through a chat-room or forum for each expert group. There follows a template of possible actions that can be followed by the expert group students: (a) they should try to concentrate as much as possible on the deeper meaning of the data they have collected during their experimentation with the provided Geogebra constructions and the materials they have studied. If necessary, they could ask their teacher for help. (b) It is important to emphasize the value of commenting on the key ideas of each specific issue at hand. (c) They should research alternative and interesting learning scenarios in order to provide a pleasant teaching experience for their colleagues. To this end, the formation of appropriate examples regarding each aspect of the notion of angle will be useful. (d) Using a wiki, they should provide their colleagues in their original groups with appropriate presentations, examples and activities that help them to better conceptualize the knowledge in question. (e) Using a wiki, they can also concentrate on the knowledge acquired during their experimentation to design a representative questionnaire reflecting the critical and not the memorizing ability of learners.

Phase 4. Jigsaw: *Back to the original group*

Each expert, on returning to the original group, should propose alternative ways to present the knowledge she/he acquired during her/his participation in the experimentation performed within a specific expert group. Here, the members of the original groups could be provided with some essential activities, so that every student can participate actively in the learning experience. Each expert should also encourage her/his colleagues to better comprehend the knowledge provided. Chat-rooms or forums could be used by each expert to teach their original groups.

Phase 5. Jigsaw: *Group Report formation*

Each group has to prepare a presentation about the total knowledge acquired during their learning process. To form this report, the use of a wiki will be useful. The use of the 'Submit Files' activity could be used to send the reports to the teachers.

Phase 6. Jigsaw: *Group Report presentation*

Here, it would be useful to provide students with some recommendations as to how to prepare and deliver a good presentation. Some guidelines can be also given to students about their actual online presentation. Online presentations could be performed by each group, using a whole-class chat or forum. During the online presentation, the teacher can initiate a 'question and answer' session to encourage experts to present their area of study in greater detail.

Phase 7. Jigsaw: *Assessment*

Each student should be set a quiz after the end of the learning activity, for purposes of assessment. The students cannot help each other during the testing process.

4. SUMMARY

This paper presented a 'learning design', dynamic and collaborative environment for the implementation of blended courses in mathematics education. For the formation of this environment the Jigsaw collaborative method was integrated with two pieces of well known open source software, namely: the Dynamic Mathematics System Geogebra and the 'learning design' based Learning Activity Management System. To clarify the features of this learning environment, a specific example regarding with the design of a sequence of collaborative learning activities for the learning of the geometrical concept of angle has been presented.

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