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Risks of Active Learning Approach: Missing the Learning Goals

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Abstract: Properly designed active learning instruction using "Hands-on" activities could result in higher student motivation and also higher teacher involvement, particularly when it implies a change from less active learning strategies (lectures, presentations) that are more commonly found in the daily life of students and teachers. Often, the expected learning improvement after these changes in instructional strategies, are assessed by standardized tests that usually assess only the declarative knowledge of the students. Occasionally, the impact of these proposals is measured by means of perception of the students. These ways of assessing fail to address the question of what really students learn in Hands-on sessions and if they really learn "better" or "more" using this kind of approach. Actually, recent research suggest that not every active learning session could promote improvements in learning, particularly in terms of conceptual knowledge and deep understanding.

The workshop describes in this paper aims to explore an efficient active learning approach for equilibrium and stability concepts. The activities proposed in this workshop show different ways in which these topics can be addressed in an active way with potentially very different learning results. After analyzing this experience, participants are asked to design another learning activity using approaches that effectively promote the expected learning. Designs and their analysis allow the comprehension of frameworks as Understanding by design or Didactical Engineering for the development of effective active learning sessions.

Key words: active learning, engineering education, didactical engineering, problem-based learning, hands-on

1. Introduction

"Hands-on" (Ho) activities are considered to develop a deeper kind of knowledge (conceptual) as well as links between theory and practice. Often, the expected learning improvement after these changes in instructional strategies, is assessed by standardized tests that usually address only students' declarative knowledge. Even if it can be expected an improvement in declarative knowledge due to the higher students motivation using this kind of activities, this is not generally the main objective. Moreover, studies show that standardized tests are not suitable for assessing this knowledge (Shavelson et al., 2005) except in case of Conceptual Inventory tests (Pellegrino et al., 2013).

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suitable for assessing students' motivation or involvement but gives few information about knowledges.

So, common ways of assessing fail to address the question of what really students learn in Hands-on sessions and if they really learn "better" or "more" using this kind of approach. Actually, recent research suggests that not every Ho active learning session could promote improvements in learning, particularly in terms of conceptual knowledge or deep understanding. For example, whether Ho is better than other approximation like virtual laboratories or more classical paper and pencil activity (Schwishow et al., 2016; Triona & Klahr, 2007; Brinson, 2015) has been discussed.

We propose to explore some active learning approaches for equilibrium and stability concepts through a workshop. The activities proposed in this workshop show different ways in which these topics can be addressed in an active way with potentially very different learning results. After analyzing this experience, participants are asked to design another learning activity using approaches that effectively promote the expected learning. Designs and their analysis allow the comprehension of frameworks as Understanding by Design (UbD; Mac Tighe & Wiggins, 2012) or Didactical Engineering (Artigue, 1988) for the development of effective active learning sessions.

1.1 Hands-on Activities and Active Learning

Prince (2004) argues "Active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing" (Bonwell C. C. & J. A. Eison, 1991). So, active learning is generally associated to problem-based learning, project-based learning and hands-on session. Some authors like Chi (2009) call this kind of activities "constructive learning" and it is considered that it implies more than simply "doing something" (Hands-on/Mind-off).

Moreover, Bonwell & Eison (1991) wrote in their report about what Active Learning is, students "must read, write, discuss, or be engaged in solving problems", namely be involved, which not necessarily implies hands-on or group activities.

In fact, the effectiveness of hands-on activities is questioned by various authors. On the one hand, the necessity of "doing something with hands" is not very clearly linked to all kinds of learnings except for young students and for some class of knowledges (Zacharia et al., 2012). On the other hand, some authors (like Schwichow et al., 2016) have showed that the cognitive load during hands-on activity could compete with deep learning. Moreover, comparative studies (Triona & Klahr, 2007; Brinson, 2015; Ma & Nickerson, 2006; Wiesner & Lan, 2004; Zacharias & Constantinou, 2008) between real laboratories and virtual or remote ones (i.e., using computer) also showed that manipulating real world is not a necessary condition to reach effective learning (for example conceptual knowledges).

In our workshop, we propose three different activities about the same concept (equilibrium): two of these activities are manipulative ones and the other one is a paper-and-pencil activity. The paper-and-pencil activity was designed using the Didactical Engineering framework we present in the following.

1.2 The Didactical Engineering Framework

One part of this workshop is based on an engineering student's classroom sequence that promotes a conceptual change in students' mind in order to bring them to understand all equilibrium situations in a suitable coherent way (Canu et al., 2014, 2016). As it is a constructivist point of view, this aim cannot be reached without the use of a student-centered teaching approach, namely an Active Learning approach. The design and the assessment of the activity are in fact embedded in the Didactical Engineering (Artigue, 1994) methodology. As Artigue said, "Didactical engineering is the design and experimentation of teaching sequences, adopting an internal mode of validation based on the comparison between a priori and a posteriori analysis within the framework of the Theory of Didactical Situations (Brousseau, 1997)". It is, with some precautions, at the same time a research methodology and a methodology to develop teaching products.

The foundation of Didactical Engineering is the Brousseau's Theory of Didactical Situations. As Brousseau claimed, "Teaching consists exactly in bringing about expected learnings in students by putting them in appropriate situations in which they will respond spontaneously by some adaptations" (Brousseau, 1988, p. 324). The (learning) situations to which he refers are real active learning situations because they cause students adaptations, namely constructions of knowledge.

The Didactical Engineering includes four steps (that we are not going to detail here):

- A preliminary analysis investigating the epistemological, cognitive and institutional conditions and constraints;
- A design and a priori analysis with particular attention paid to the identification and selection of values for the didactic variables and anticipation of their potential effect on the "students-milieu[1]" interaction;
- An experimentation;
- And a posteriori analysis and validation of the hypotheses underlying the design.

Here, participants experiment only one part of the entire didactical sequence designed for the students as it consists normally in two 1h30 sessions.

1.3 Active Learning Design

During the second step of the workshop, participants are asked to analyze the activity they experienced. In order to do that, we propose to use a guide based on the Understanding by Design framework (UbD).

UbD is a curriculum design framework based on an assessment perspective. The knowledges assessment of a learning sequence is included in the firsts steps of the activity design in order to insure an exact match between the activity and the expected knowledges. Effective curriculum is planned backward from long-term, desired results through a three-stage design process: Desired Results, Evidence, and Learning Plan. Even if this framework was developed to curriculum design, it can be used to guide sequence design inside this curriculum. For that, six facets of understanding — the capacity to explain, interpret, apply, shift perspective, empathize, and self-assess — can serve as indicators of understanding. This process helps avoid the common problems of treating the textbook as the curriculum rather than a resource, and activity-oriented teaching in which no clear priorities and purposes are apparent.

The proposed backward design is composed of three stages guides by some key questions (Mac Tighe & Wiggins, 2012, p. 2):

First stage: Identify Desired Results

Key Questions: What should students know, understand, and be able to do? What is the ultimate transfer we seek as a result of this unit? What enduring understandings are desired? What essential questions will be explored in-depth and provide focus to all learning?

Stage 2: Determine Assessment Evidence

[1] For more details about this notion of *milieu*, which is more than a simple *social environment*, read Brousseau (1988), *La théorie des situations didactiques*, La pensée Sauvage, pp. 115–160, Grenoble.

Key Questions: How will we know if students have achieved the desired results? What will we accept as evidence of student understanding and their ability to use (transfer) their learning in new situations? How will we evaluate student performance in fair and consistent ways?

Stage 3: Plan Learning Experiences and Instruction

Key Questions: How will we support learners as they come to understand important ideas and processes? How will we prepare them to autonomously transfer their learning? What enabling knowledge and skills will students need to perform effectively and achieve desired results? What activities, sequence, and resources are best suited to accomplish our goals?

As said before, UbD is originally shaped for curriculum design but it is possible to use it as an activity or small sequence design. This framework is also used by participant to analyze the three firsts activities, in the second step, as well as to attempt to improve them, in the third step of the workshop.

2. Activities

The aim of this communication is to show, through a well design workshop, that not all hands-on activities lead to knowledge acquisition, or, in some cases, drive to useless or irrelevant knowledge learnings with respect to the concepts goals. In fact, many active learning sequences or sessions are not design from clear learning objectives. Frequently, the practical or manipulative aspect is the only clear explicit objective while the professor wants to reach many other implicit objectives. The main goal of the workshop is to drive the participant to identify the real-effective-learning objectives in the three activities and to learn some elements that allow a more effective learning activity design.

As said before, the participants are involved in three different activities (Hands-on and Hands-off) around the same concept, each of them driving to different knowledges:

Pendulum control activity (Hands-on)

Equilibrium cases study (Hands-off, like in Canu et al., 2014, 2015)

Prototypic arm balance activity (Hands-on)

Participants are shared in small groups in order to probe one of the three activities. Then, a short presentation of each activity is organized so as to share each activity with the others and to discuss the presumed learning objectives of each one. The second step consists in analyzing each activity with the UbD methodology in each group. In the third step, participants are asked to attempt to improve the design of each activity if it is possible, using the same framework.

2.1 First Step: Group Activities

After a short organization phase each group receives a document with the description of the proposed activity as well as some material depending on it. In this step, participants experience the activities as student would do it.

In the pendulum activity, participants should handle a metallic pendulum in order to find some important variables that rule the pendulum equilibrium. They have to design some experiments so as to find these variables as in an inquiry-based activity.

In the arm prototypic balance activity, participants should handle a metallic couple arm/fulcrum and some counterweights in order to find important variables and rules that determine the balance equilibrium. They have to design some experiments so as to find these variables as in an inquiry-based activity.

In the paper-and-pencil activity, participants are asked to define the equilibrium concept analyzing some fundamental and well-chosen situations (Canu et al., 2014, 2016).

At the end this step, each group is asked to expose the content of its activity to the other groups. They are invited to answer some questions about the presupposed learning objectives of each activity, and discuss those objectives with the others. The aim of this debate is to test the participant ability to find explicit or implicit learning objectives in the proposed activities. Participants have also to define if each situation is an active one, and why.

2.2 Second Step: Activity Analysis

In fact, few variables are controllable in the two hands-on activities, so only some aspects (and not the most important ones) could be managed. In consequence, only very limited knowledges about the concept could be reached:

In the pendulum situation, only the distance between the rotation axle and the pendulum centre of mass can be changed. As the pendulum possesses only two equilibrium positions independent of the centre of mass position, a very limited knowledge about the equilibrium concept can be acquire.

On the contrary, in the arm balance situation, as the fulcrum can be moved along the arm, it is then possible to design richer experiments in order to investigate the system variables and rules (for example, the Archimedes law of the lever). Nevertheless, only horizontal equilibrium positions can be reached. This implies also a quite limited knowledge of the concept.

In the paper-and pencil situation, participants have to define the concept of equilibrium from the study of three systems: an equal arm balance, a pendulum-on-a-cart system and a book on a table. In this activity, there is a frail hands-on aspect contrary to the others. But, due to the adopted methodology (Didactical Engineering), we can ensure a minimum level of understanding in the students/participants.

In this step, participants are asked to analyze the situation proposed in his/her group using the UbD key questions described above. They are expected to detect the gap that exists in some situations between the learning objectives and the knowledges promoted or induced by the situation. The key concept here is the didactic variables (Brousseau, 1997) and their role in the behavior of the participant/student in front of such situations. Here, the nature of the studied system is one of these didactic variables. Didactic variables are fundamentals because they constrain the problems studied by students in an activity and drive their behavior. So, through this behavior, they induce or prevent learnings in an implicit manner (Canu et al., 2014).

Many hands-on activities, like the pendulum situation or the arm balance situation, lean on the use of too specific situations. Many times, the choice of these situations is not the product of the learning situation design but the result of some preceding choices (the existence of some material in the professor laboratory is sometime the cause of such a pre-choice). One of the aims of this step is to question this kind of implicit choice. During the analysis of the three situations the participants are expected to detect this lack of adequate connection between situations and learning objectives in the first's two situations.

The host gives some basic elements of the Didactical Engineering methodology during this step.

2.3 Third Step: Design Activity

With the same tool (the UbD key questions), the participants are invited to find some ways of improvement for the two hands-on situations. They have to study two ways: the first one is to change the situation and the second one is to redefine the learning objectives of the situation, in order to reach a more accurate match between these two elements.

3. Expected Results

This workshop described here drives the participant to a deeper understanding of the link between learning objectives and activity in the framework of active learning. They are expected to understand the bases of two design methodologies, the Understanding by Design and the Didactical Engineering one. They are also expected to understand some of the limits of hands-on activities and to be able to decide what kind of activity could lead to what kind of knowledge.

4. Conclusion

While “Hands-on” (Ho) activities are considered to develop a deeper kind of knowledge (conceptual) as well as links between theory and practice, many Ho activities produce a low level of conceptual understanding. This can be explained by a focused on purely manual activities that produce a cognitive load or prevent transferable knowledges to other situations when the teacher doesn’t promote conceptual science scaffolding (Hattie, 2009; Hmelo-Silver C. et al., 2016). The design of a manual-centred activity also often lead to neglect some of the main conceptual learning objectives of the task. The combination of the Understanding by Design and the Didactical Engineering methodologies could help to prevent those drifts: the first by helping the didactical sequence designer to keep in mind the learning objectives during the design process; and the second by bringing fundamental elements relative to the student knowledge construction during learning situations (activities) design.

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