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FLIPPED LEARNING LESSON PLANS ON THE SCIENCE CENTER EXPERIMENTARIUM IN COPENHAGEN

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Abstract

Though most teachers find formal learning activities an important part of a class visit to a science center, research indicates that formal learning is seldom the outcome. Instead visits tend to become "soda visits" without preparation, learning goals, and connection to the subjects taught back in school. [1, 2]. To accommodate these challenges at the Copenhagen science center Experimentarium, they started a partnership with the teacher education at University College Copenhagen in 2017. In the collaboration, eight flipped learning lesson plans were developed to assist the visiting teachers frame the teaching before, during, and after the visit [3]. This paper investigates the actualized learning potential [4] throughout one of the lesson plans (”Dikes and gates”). The objects of the analysis and investigation are 24 8th grade students and their teacher as they engage with the learning materials. The data is analyzed with Engeström´s activity theory [5] and the notion of hard and soft scaffolding [6, 7, 8]. The data production consists of sound recorded teacher interviews, sound recordings of the lessons, and recordings of selected student’s view by videoglasses during the learning activities. Though the 8th grade teacher finds learning material essential as a tool for scaffolding formal learning for visiting classes, multiple contradictions are identified between the design of the learning material and the actual usage. This indicate the need of a tool to identify the complex relations in the context of development of flipped learning materials on science centers. A preliminary model for such a tool is presented here.

1 INTRODUCTION

In the following, we will introduce the challenges for visiting classes within the science center context, the flipped learning concept as the tool to overcome these challenges, and finally, the scaffolding theories as a focused view on the mediation of the learning processes.

1.1 Formal Learning in a Science Centre Context

Experimentarium as a science center is a popular attraction that offers great recreational and learning possibilities. Ted Ansbacher divides museum visitors learning outcome into 7 categories, which we believe apply to science centers as well: 1) No outcome, 2) add to experience bank, 3) develop physical knowledge, 4) change feelings or attitudes, 5) lead to active curiosity, interest, or awareness, 6) achieve understanding, and 7) develop skills [9]. Though all the outcomes are equally valid (even “no outcome”), this paper focuses on the formal and explicit learning, more specifically on the development of the student´s conceptual understanding. According to Sørensen and Kofod [1], most teachers are also focused on the student´s formal learning outcomes when visiting Experimentarium, though they seldom have the tools or the time to set up a framework which facilitates this [1]. These findings are according to Sørensen and Kofod quite similar to the findings within multiple foreign investigations [1]. The difficulties of learning within the science center setting are, at least partly, caused by the lack of planning, the many impressions, and a high level of noise. This ultimately leads to the students “zapping” around in the exhibition, instead of focusing and experimenting with a few select models [1]. The eight flipped learning lesson plans developed in 2018 were aimed at helping teachers facilitate a more in-depth learning experience, resulting in the student´s more formal learning.

1.2 Flipped Learning Approach

According to Eppard and Rochdi, flipped learning is used in a great variety of meanings: “There is a lot of freedom in the manner in which teachers present information and plan lessons, and students synthesize the content.” [10]. Also, researchers present a wide variety of definitions, which calls for this paper to be clear on the components of the learning design within this investigation. The next

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three headlines represent the more general aspects of flipped learning, whereas the “FLIP model” is the specific model that inspired the development of the lesson plans investigated in the paper.

1.2.1 *Mediated Learning*

Most researchers agree that flipped learning offers some sort of digitally mediated learning for the students, and that some of the mediated parts are carried out outside class in an individual learning space [10, 11]. Bishop and Verleger explicitly reject definitions of flipped learning which do not include videos as an outside class activity [12]. The mediated learning typically offers instructional videos covering low taxonomy learning objects, which often replace the lecturing parts of the in-class teaching. These videos can be watched at any time and are therefore considered asynchronous learning tools. Whereas the video is considered mandatory for the flipped learning concept, there is a wide variation of examples that use asynchronous close-ended problems or quizzes as an addition to the homework.

1.2.2 *Integrated Learning Experiences*

Horn and Staker´s framework for flipped learning is not only a mix between online mediated asynchronous learning resources and the physical classroom. Within the definition also lies a demand for a meaningful learning design: “... the modalities along each student’s learning path within a course or subject are connected to provide an integrated learning experience”. This means that it is not enough to mix in a video into an existing lesson plan, since every part of the learning design is interconnected, calling for adjustments all around the design to create the “integrated learning experience”.

1.2.3 *Active Learning*

“Flipping” indicates how some elements of the teaching are mediated and reordered, but the pedagogical approach is an equally important part of the definition of flipped learning [12]. Flipped learning needs to be build on the notion of active learning. Active learning can be defined as “any instructional method that engages students in the learning processes” [12]. The more practical pedagogical approaches to the broad term of active learning cover peer-assisted learning, cooperative learning, collaborative learning, peer tutoring, and problem-based learning (12). These methods are student-centered, in contrast to traditional methods centered around the teacher and a blackboard. Horn and Staker specifies that the students should at least have “... some element of student control over time, place, path, and/or pace” [11]. The learning theories behind these methods include a vast variety of constructivist theories, to mention a few: Piaget's cognitive constructivism, Vygotsky’s social constructivism, and Dewey’s pragmatism. In this paper we will go further into explaining and applying the scaffolding theories of Vygotsky’s notion of zone of proximal development.

1.2.4 *The FLIP Model*

The University College Copenhagen (UCC) research department has developed a model which is used in the research project “Flipped Learning in Science Education”. A 500,000 € research project, where the goal is to educate school teachers in using the method [13]. Since UCC has also developed the flipped learning materials at the science center, the following FLIP model has inspired the lesson plans developed at the Experimentarium, including “Dikes and gates” which is investigated here. The model is a 4-phase model, which rotates between two learning spaces. Learning space 1 could be homework for the students. Here, the student watches a video and answers learning questions.

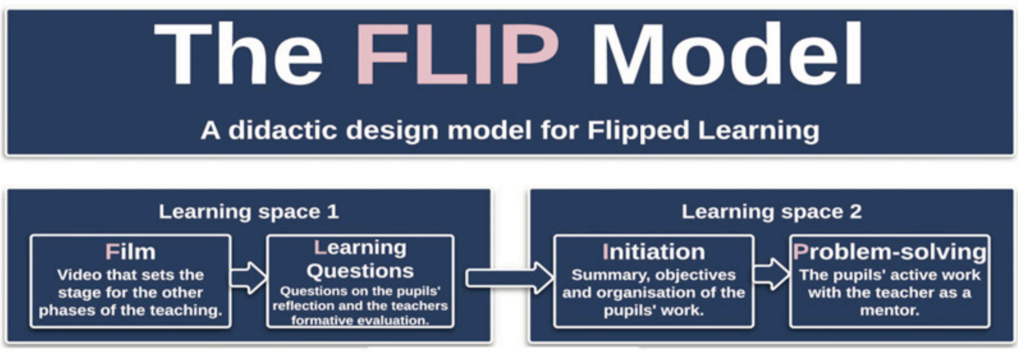

Illustration 1. The FLIP Model developed by UCC [13]

This mix of instruction and learning activity has two purposes: 1) to activate the content of the video to help the student understand and remember the basic concepts and 2) give the teacher a chance to get insights on the student´s learning pre-requisites before class by investigating the student´s answers [13]. In class, the teachers use their professional knowledge to frame the student-centered learning activities. These activities could be problem-solving with the teacher as a mentor, or other forms of active learning. The FLIP model also refers to Bloom´s taxonomy, aiming the instructional design at the lower levels, and the active learning processes at the higher levels [15]. This model is build on both the American flipped learning-concept and the constructivist theories, but also on a Nordic pedagogy with less focus on curriculum and more focus on ”bildung”.

1.3 Artefact Based Scaffolding

In Vygotsky´s zone of proximal development and Bruner´s scaffolding concept, the learning process is dependent on (or at least helped greatly by) the learner's interactions with an expert. The novice-expert relation is often exemplified with the relationship between a parent and a child or a teacher and a student. Though in the later years, the term of scaffolding has shifted towards a broader understanding of the term and now often includes artefacts [6, 7, 8]. Bruner´s academic apprentice Roy Pea argues that "Scaffolding is no longer restricted to interactions between individuals - artifacts, resources, and environments themselves are also being used as scaffolds." [6]. Puntambekar and Hübscher divide scaffolding into the "original notion of scaffolding" and the "evolved notion of scaffolding" [7], which Brush and Saye simply call "hard and soft scaffold" [8]. The evolution model suggests that the evolved version is the current notion, but here we will consider them as coexisting, and use the terms hard and soft as synonyms to the original and the evolved.

Feature of Scaffolding	*Original Notion of Scaffolding*	*Evolved (Current) Notion of Scaffolding*
Shared understanding	• Adult or expert establishes shared understanding of common goal and provides motivation	• Authentic task often embedded in the environment; provides a shared understanding
Scaffolder	• Single, more knowledgeable person provides support to complete the task	• Assistance is provided; tools and resources
	• Multimodal assistance provided by a single individual	• Distributed expertise—Support is not necessarily provided by the more knowledgeable person, but by peers as well
Ongoing diagnosis and calibrated support	• Dynamic scaffolding based on an ongoing assessment of the learner (individual)	• Passive support—Ongoing diagnosis by peers and or software is not necessarily undertaken
	• Adaptive scaffolding—Support is calibrated and sensitive to the changing needs of the learner	• Blanket "scaffolding"—Support (especially in tools) is the same for all students
Fading	• Eventual fading of scaffolding as students become capable of independent activity	• In most cases, support is permanent and unchanging

Illustration 2. Puntambekar's and Hübscher's Evolution of the Notion of Scaffolding [7:7]

The table shows four key elements of scaffolding (to the far left), and lists the most central differences between hard and soft scaffold for each. The advantages of the hard scaffold are the scalability – there is only one teacher for an entire class, but a 1:1 ratio for smartphones or computers. And, if that is not the case, paper handouts can also be considered hard scaffolds. The hard scaffolds however can not adjust itself to the specific needs of the learner, but are the same for all students – like a blanket covering all, no matter their needs. Though adaptive computer software can be seen as some sort of blend between the two (or even defined as a third generation scaffolding), the lesson plans at Experimentarium are not considered adaptive. Some aspects entangled within the table are worth mentioning: First, the importance of a shared understanding of the activities. This understanding has normally been negotiated between students and teacher, but can now be more or less guided by the hard scaffold. Secondly, the hard scaffold can facilitate soft peer processes. This is interesting, because it makes the soft scaffold scalable. However, according to Tudge 1990, there are no guarantees for the effectiveness of the soft scaffold, even though high levels of interactions are seen between a competent and less competent student (referred from Puntambekar and Hübscher [7]). Thirdly, though the hard scaffolds might take over some parts of the teacher's role, they are not in any risk of getting replaced anytime soon. "To orchestrate all the activities and integrate the tools, the teacher plays the most important role." [7]. One final point in this chapter would be, that since the evolve of the scaffolding term, the complexity of researching further, calls for investigating "... how students are actually using the tools, and the kinds of learning that the tool promotes in students who are at varying levels of understanding..." [7]. This investigation is what we aim to take part in.

2 METHODOLOGY

In the following we present how scaffolding and activity theory is used to find the actualized learning potential of a class using the flipped learning material, and how data is produced, and the case selected. Note, that this paper is a part of a larger holistic investigation focusing and concluding on two additional aspects inspired by Bundsgaard and Hansen [4]: 1) The learning potential of the flipped learning lesson plan, using cognitive load theories [16, 17] and 2) measuring the learning outcome using personal meaning mapping [2] before and after the visit. For further reference, see Philipps, 2018 [18]

2.1 Actualized Learning Potential

The actualized learning potential is according to Hansen and Bundsgaard "… the potential for learning when the design for learning is enacted by integrating the learning material in a situation in a given context" [4]. As a theoretical tool to understand this context, we are going to use Engeström's activity theory to discover contradictions within the activity systems. The scaffolding theories are used to explain and discuss these contradictions.

2.2 Activity Theory

Engeström's activity theory is a third-generation theory built on Vygotsky's notion of learning being mediated by cultural artefacts in a context bound by common and individual historicity. "The individual could no longer be understood without his or her cultural means; and the society could no longer be understood without the agency of individuals who use and produce artifacts." [5]. Engeström's model of activity allows analysis of complex contexts, since it can map relations between individuals, groups, or larger corporations. The analytical framework is not aimed at finding simple correlations or causalities, which is why the object of the analysis is a complex interactional system of "... collective, artifact-mediated and object-oriented activity system, seen in its network relations to other activity systems…" [5]. As explained earlier, learning at Experimentarium is a complex, mediated experience, which is why we have found Engeström's tool for analysis suited in the context.

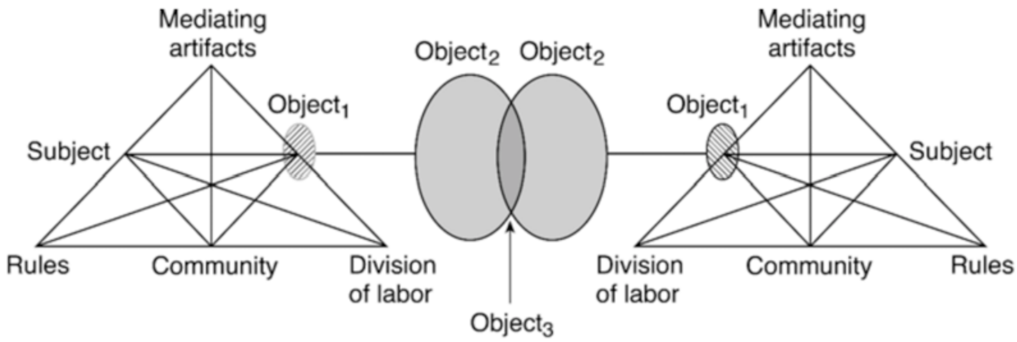

Illustration 3. Model of Engeström's third generation activity system theory [5:136]

2.3 Qualitative Data Production

Illustration 4. A300 HD videoglasses used by the students during their learning activities.

Our primary source of data is the A3000 HD videoglasses. Fitting on the nose of the students, recording in the direction of their head, they allowed us to come near the interactions without being too intrusive. Audio recordings where made with a Zoom H2n audio recorder.

2.3.1 Data overview

Table 1. *Overview of data production*

	Total video	Video sequences	Total audio	Audio sequences
Before	31 min	3	30 min	1
During	240 min	6	29 min	1
After	100 min	3	45 min	1
Teacher interview	-	-	1:23 min	1

2.4 Transcription of Data

The recordings from the classroom served as a reference to the classroom framing and have not been transcribed. Whereas most of the teacher interview has been transcribed, the video material is far too dense and massive to transcribe within this frame. Instead the videos were skimmed for interesting situations, regarding the interactions between the exhibition artifacts, lesson material and teacher. The small sequence presented in the case was transcribed in both wording and from what interactions we interpreted to be relevant for the analysis of the situation.

3 RESULTS

The following chapter is based on the activity system analysis. This analysis creates an overview of the different aspects of the relevant relations during the visit, an in-depth case analysis from a single group´s work in the exhibition, and finally, the perspectives of the teacher to broaden the understanding.

3.1 Activity System Analysis

From the observations and going through the produced data, the following analysis slowly formed. It presents an overview of the different aspects of each system – respectively the students as a collective and the teacher as an individual. This map of relations is used in the next chapter to better understand the presented and analyzed case. It is primarily the student side of the table which is of interest regarding the case, but also the object on both the student and teacher side should be noted.

Table 2. *Student and teacher activity system analysis.*

Subject	Students	Teacher
Historicity	Diversity in learning pre-requisites. Not easily impressed. From high standard school.	Educated, experienced. Insight into student's pre-requisites. The visit is out of context regarding planning of the year.
Tools, signs	Scaffolding: Videos/questions on phone. Functional: Ruler, phone, water etc. Semantic: Internet access.	Teacher guide ("Dikes and gates"). Other learning materials (Clio online).
Object	Following what is expected (school/social). Learning, understanding, experimenting.	Student learning (concepts, methods, common experience). Student attitude.
Rules	Teachers framing (soft scaffold). Material of framing (hard scaffold).	Regulations (government/school). Timeframes.
Community	Peers in class.	
Division of labor	Groups and subdivisions: "Leader", "Ruler", "Note-taker".	Conducting teaching.

3.2 Artefact Based Scaffold in “Dikes and gates”

The following focus is on the scaffolding interactions happening during the visit. First, a brief description of the lesson plan is presented in order to put the analysis into context. Then a single case is presented and analyzed to give a narrow and deep view into the empirical data. Lastly, the teacher´s view on the overall teaching is presented to put the single case into perspective.

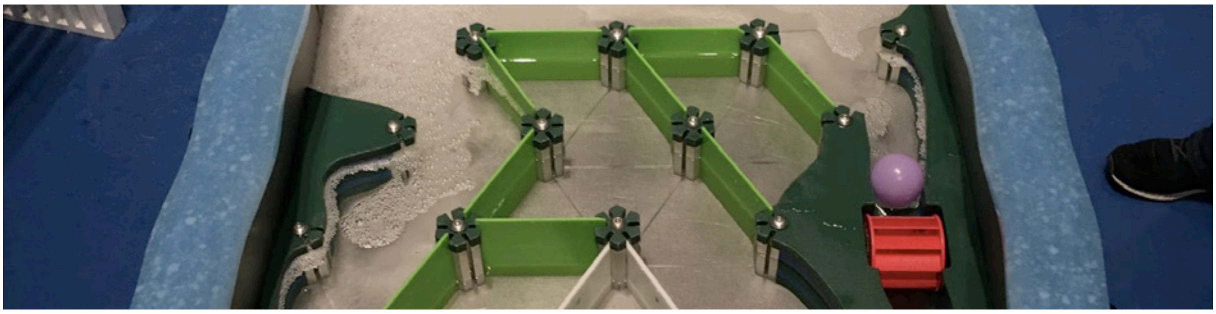

Illustration 5: “Dikes and gates”

“Dikes and gates” is a model of a river which can be altered to adjust the rotation speed of three red mills. The flipped learning lesson plan is designed for scaffolding student’s active learning about the theme of water power. More specifically, the students measure and calculates all the elements necessary for them to calculate the potential energy of the water stream by the mill: $E_p = m \cdot g \cdot h$. The learning objectives during the investigation is about being able to a) design and conduct a systematic investigation b) discuss sources of error, and c) designing alternative systematic investigations themselves. Furthermore, the students should d) develop their investigational competencies and be able to e) understand water power in a more global sense. The questions are guiding the students step by step. Some of the concepts are applied at school, others during the visit. Prior to the visit, the students have 1) seen a general video about water´s effect on human life, 2) seen a conceptual and guiding video aimed at the specific activities revolving “Dikes and gates” and 3) been working with questions to scaffold the student´s understanding of the video content, thus preparing them for the activities during the visit. During the visit, no group manages to complete all of the questions despite a very well-organized and experienced teacher, relatively focused students, and with only 7 student groups which is below the material´s recommended amount – the work load is simply too large to be completed within the given timespan.

3.2.1 Case: The Leader, Ruler and Note-taker.

The following case has been selected because it shows the dilemmas between hard and soft scaffold. Though this group consists of two girls who can be considered strong and focused students, most of the patterns are seen in the other groups as well.

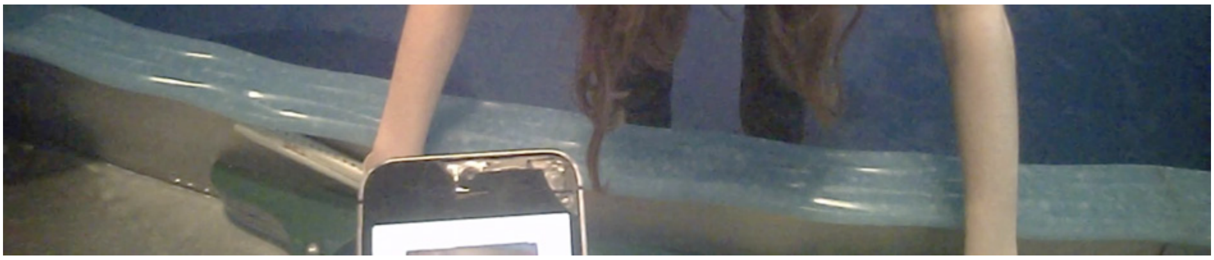

Illustration 6: Snapshot of the video sequence with the Leader and the Ruler.

During the visit, in a group consisting of two girls and two boys, the division of labor is quickly established. The Leader as we call her here (wearing the videoglasses), is taking command, and while deciding to hold the phone she is in control of the task at hand. The Ruler is both the one holding the ruler (to measure distances) and the girl second in command. The third group member (boy) is given the task of taking notes and other tasks such as calculating elements in the Google Form. The fourth member plays a very little part of the actual task at hand. The teacher kicks of the group by helping them find the starting position of the gates, then leaves. One by one, the leader guides the group through the steps, primarily through dialogue with the Ruler, and when necessary, with the Note-taker. The Leader and the Ruler are focused on the task from the material and they collaborate in dialogue about where the best measures are taken and how to calculate the results. The Note-taker has his attention elsewhere, but comes when called upon and does more or less as asked. 3 minutes has passed since the teacher helped set up the gates, and the boys have been occupied with the little whirlpool of water which provides water for the model river. They have been altering the speed of the whirlpool, so water is now coming down faster, rising the river water – and ruining the Ruler´s former measurements. The teacher comes over and asks the group: "Are you able to do the calculations?" (referring to the learning material). Seeing what is happening, he changes his focus to the activity regarding the whirlpool and its effect. One of the boys exclaims that they now have to measure again, but the Ruler stands confused, unaware of what happens up stream (1.5 meters away): "Yes, why did the water height change? No one altered the gates". The teacher picks up this question, addressing the whirlpool experimentation, and tries to make the group realize the connections between the water height and the boy's experimentation. He is quickly silenced though, when the Leader takes control by referring to the next step in the task (please note, that this situation is considered acceptable on a Nordic school context). They move on.

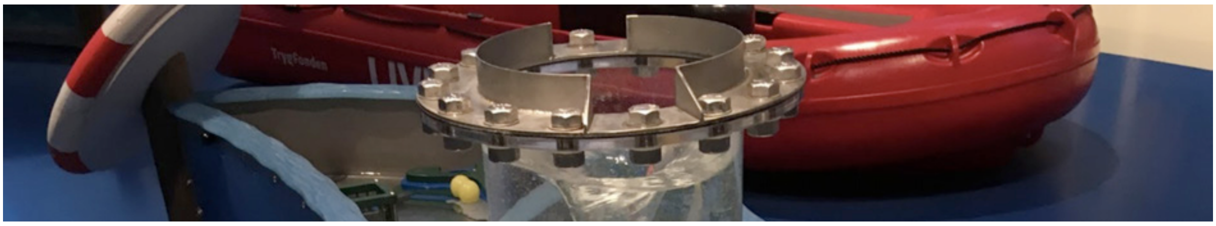

Illustration 7. Top of the whirlpool, affecting the water stream in the river.

3.2.2 Analysis of the case

The example shows many things, and in the following two points are analysed. For one, the hard scaffold creates a certain mode of activity. Connie Svabo calls this "modus" [19]. In this case, two of the group members are focussed and working on the task with the goal of completing it. The Note-taker (and maybe the fourth member) is experimenting more freely, challenging the whirlpool. They are quite aware of the whirlpool´s effect on the rest of the river system, which the teacher seems to find interesting within the subject of geography, trying to scaffold further curiosity or reflection on the phenomena. But, even though he is the teacher, and the Leader is only a student, he withdraws from the conversation because the girls are right – this is not what was meant to happen. This contradiction can be seen in the activity system analysis as the difference in the student's diverse understanding of objects (to follow expectations or to experiment), which is aligned with the duality of the teacher's conception of objects (curriculum learning and attitude). In this case, the rules of the material framing dominate the rules of the teachers framing. Another aspect to be discussed is the division of labor itself. What does the individual students gain from the cooperation and each of their roles? It seems like the Leader and the Ruler are having discussions and activities that are within the learning design, but the Note-taker does not really seem to be engaged in the intended design. Maybe, he is helped by the more dominant students, maybe he is prevented from learning in his own way. Even though the teacher notices the learning possibilities, he is not allowed to provide soft scaffolding. Maybe they would all learn more if the student roles where switched around, or the groups where more homogeneous (which is the opposite of the teachers group selection).

3.2.3 The Teacher Perspective

According to the teacher, the division of labor is not without challenges: "I think that one of the weaknesses was, that the one writing the results and leading the investigation was way more into the investigation design, than the others where.". Though pointing out this problem, the teacher also finds that some of the processes function in the established student roles. "In the collaboration about discussing where to measure the length, and the height, there… it was my experience that they were all engaged in dialogue and processes […] when you are in a group of three or four, there will always be one that takes control". Regarding the student's opportunities to all bring forth their phones and working questions, the teacher points out the specific problematic relations regarding this model and the designed exercise: "I think that the combination of water, mobile phones, and rulers was difficult, because we did tell them that each and every one should have the phone and the questions turned on, but that didn't happen in any of the groups. One had the phone and had the task of reading out loud to the others". The teachers understanding of the exercise (that every student should be using their phones) is not aligned with what the students find necessary precautions when they meet the model (keeping their phones out of water, using their hands for other activities etc.). We would argue that this is a contradiction between the learning material (tools), and what seems necessary for the students to consider in the meeting with the model, and that this is calling for an adjustment in the material design. Regarding the teacher's role, the observations clearly state the need of a teacher to frame the teaching, organize the groups and keep most students focused on some sort of learning activity. This comes natural to the teacher who does not address these elements during the interview. The teacher's importance is aligned with the literature […]. In this particular learning material, the teacher positions himself as a more technical assistant, or even knowledge database, during the student´s use of the material: "I actually think that they used me really well by asking questions. Most of it was technical things… for instance about the cross section [in the water] which they kept discussing." In one group he even helped writing down results, because they needed more hands, due to the number of artifacts. Though both the students and the teacher are disappointed that the learning material does not leave room for the more free experimentation, the teacher finds the learning material essential for his task as a teacher: "If I were to draw some substantial geographical concepts out of a more loose, playful approach to this model, I need to know way more about the subject. I could imagine, that it would have been hard for me to try to sum up when we get home, other than, this gate should be like this, and that gate should be… if we should connect theory to our experience." The common learning experience should not just be viewed isolated, but in a historically accumulated context of the class: "I think this one will become a good one to return to [common experience], that we have actually been out here and doing something else than simply being here [at school]."

4 CONCLUSIONS

Though the class use of the material indicates some built-in contradictions (e.g. phones and water, experimentation and step by step assignment), the teacher finds learning material essential for a more formal learning experience. For the teacher, the exhibition offers foreign artefacts in a foreign learning environment which is difficult for the teacher to adapt to the diverse classroom context and frame into a meaningful common learning experience, which the school regulations call upon. The learning materials can create a shared understanding of what to learn, and which learning activities are needed to get there. But the learning materials should be seen in the complex context in which they are to unfold; A class visiting the exhibition with the teacher interpreting and framing these materials. Visits tend to be a complex situation, calling for a learning material design process taking the relevant factors into consideration, and finding a balance across these relations. Below is given a preliminary view of such a model which will be unfolded in the full research design [18].

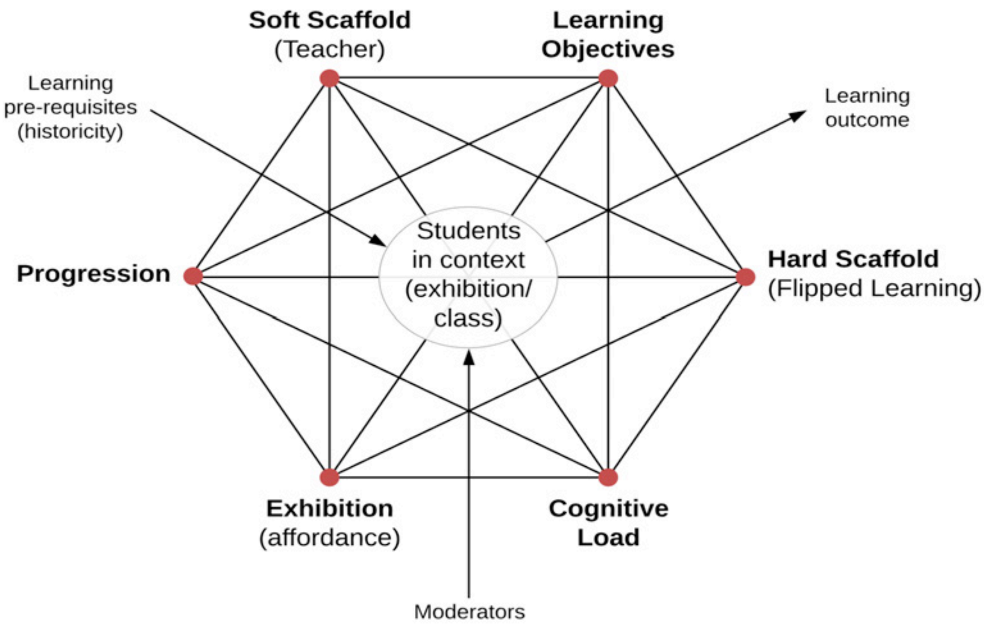

Illustration 8. Flipped Learning Science Center Model

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