Hanging Pictures or Searching the Web: Informing the design of a decision-making system that empowers teachers to appropriate educational resources to their school's infrastructure[1]

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Abstract. In this paper we report work in progress describing how we address the problem of infrastructure by creating a decision-making system that will help teachers to adapt existing ICT scenaria to their practice and to their school's infrastructure by proposing alternative technological solutions with the same or similar functionalities. If a scenario dictates for the students to "take this picture, frame it, and hang in on the class wall using a hammer and a nail provided", it does not take a very innovative teacher to replace the hammer with a stone and find an old throw-away nail somewhere, if the tools specified are not available; depending on the situation they might also just blue-tag the unframed picture on the wall. Whether each of the substitutes is educationally equivalent depends on the teaching method, the learning context and goals. Searching the Web for appropriate monument pictures can be an ICT-enhanced elementary student activity, this one requiring individual access to computers and the Internet; supposing it is part of an educational scenario, it can be accomplished with phones rather than computers; it can be substituted by students taking pictures of actual monuments; or scanning monument pictures from magazines; or even by interviewing parents about the history which the monument commemorates. Again, the suitability of each of the substitutes is determined by the teacher. The eSIT4SIP methodology (http://www.esit4sip.eu), based on an ontology capturing concepts of learning and media technology, results in the analysis of a scenario into its constituting elementary activities (micro-activities); the explicit specification of the affordance of the ICT tool that allows the m-activity to take place; the description of the educational functionality accomplished; and the extraction of the teaching approach, which constitutes the Instructional Design Pattern of the scenario. For each m-activity the knowledge base of the eSIT4SIP decision-support system provides (1) alternative technology with the same or similar affordances and (2) alternative micro-activities with similar educational functionality. These may lead to learning-equivalent scenario variations feasible with the existing school infrastructure. The Instructional Design Patterns act as guides for the acceptability of the variations.

Keywords. Educational scenarios, micro-activities, educational innovation

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1 Introduction

Educational technology moves much faster than pedagogical innovation. This leads to the paradox of schools never having enough ICT while this very ICT is underutilized. Teachers willing to at least try out innovative technology-enhanced educational scenaria are often stopped by perceived lack of necessary equipment. But "can I do this with my existing school infrastructure?" may be unnecessarily getting negative answers, as obvious and non-obvious substitutes exist. While most teachers know about open source alternatives to a piece of software they do not have, they may need to be told that a shared document (e.g., Google Docs, cryptpad) can play the role of an interactive whiteboard, thus representing a not so obvious replacement for a piece of hardware described as being essential in a learning scenario identified by a teacher as desirable. In this paper we present a systematic approach to answer the question "Can I do this (ICT-enhanced lesson) with my school's infrastructure?". We start with a structural analysis (break up) of the educational scenario, leading to sequence (or web) of 'micro-activities', for each of which alternatives with other equipment may exist. It is up to the teacher, and depends on the learning context and goals, whether each of these alternatives is an acceptable alternative or not. Our analysis is backed by an ontology-based knowledge base system, which will lead to a full-fledged decision support system for the purpose.

2 Theoretical background

In early discussions about the integration of ICT in education, availability of resources was one of the contextual forces impeding the use of digital technologies in the classroom [1]. Today the situation is very different as teachers are exposed to numerous learning resources through platforms, be they open (PhET, i2geo, LeMill, Curriki, EduTags), from textbook or learning tools publishers, or more social network oriented (e.g., OpenDiscoverySpace, eTwinning, YouTube for Schools, Canvas LMS). While these platforms offer widely available learning scenarios and, sometimes, experience reports in particular contexts, their current impact on schools and teachers remains low [2]. Our observation is that each of these contributions are quite isolated and the deployment within the school infrastructures is often inexplicit. Lack of infrastructure used to be, and in some cases still is, a problem for ICT integration [3]. However, today the problem of infrastructure has been transformed to an issue regarding the type of infrastructure available and teachers' access to it, connecting thus the infrastructure to the school and/or national policy [1, 3, 4].

The paradox of choice (i.e., *more is less*) that applies in the availability and use of resources has another facet, which is related to the grainsize of resources available, and the way teachers use these resources [5]. A full -fledged scenario (lasting several hours) or a lesson plan, is difficult to be implemented as such in another classroom for reasons related not only to curriculum, and context (i.e., classroom, school, country) but also to teacher's personal epistemologies and pedagogies (see also [5] for the reasons influencing the use of resources by the teachers). Furthermore, appropriation of this type of resources is often time consuming and requires a lot of effort in order to overcome cultural, contextual, methodological barriers. This is not to say that a scenario or a lesson

plan is not useful as a resource; instead, in order for the teachers to be able to use it, we argue that it is important to address teachers as designers and not as users.

These observations are backed by the work of Gueudet, & Trouche [6], which highlight that the use of resources by the teachers does not involve simply implementation of what they (the teachers) find available. Instead, it is a complex and demanding process involving a continuous dialogue between design and enactment. More specifically, teachers using existing knowledge, considering the context and the specific instructional situation, influenced by the institution and the community they belong, embark to: select resources, combine different pieces of resources together, test them in their class and revise the initial use (ibid). To capture this complexity, Gueudet, & Trouche (ibid), describe the use of resources in practice as documentational genesis. Documentational genesis consists of two elements: a) the resource and b) the development of a utilization scheme, which involves the appropriation and transformation of the resource in order to solve a specific problem or to achieve a type of task (ibid). Documentational genesis is mediated by two intertwined processes a) Instrumentalization: where teachers appropriate and shape the resources (i.e. in our case educational scenarios / lesson plans) using their existing knowledge and b) Instrumentation: where teacher's interaction with the resources (i.e. inspection, appropriation etc) enriches and shapes teacher's knowledge and practice.

Our approach for the structural analysis of scenario and the design of the recommendation system, is informed by the theoretical analysis on teachers' use of resources, in the following ways: a) We break up the scenario into micro-activities (which can lead back to the initial scenario) in order to facilitate the process of appropriation, selection and combination of different pieces of resources; b) We provide connections of micro-activities to different types of infrastructures in order to facilitate the instrumentalization process (i.e., adaptation of resources by the teacher); c) We design recommendations for adaptation of micro-activities based on technology functionalities and different contexts of use, aiming to support the instrumentation process (enrichment of teacher knowledge). The purpose of the latter is to attend to the creative dimension of teaching and address teachers (also) as designers. Fischer et al [7] highlight that creativity can emerge in contexts where people experience breakdowns (i.e., when they experience something they can't do). Considering that our overarching question "Can I do this?" is also a fertile ground for creativity, we provide recommendations to apply solutions to other contexts, structure the investigation of alternatives (analysis of infrastructure functionalities) and support the decomposition and manipulation of partial solutions (micro-activities) [8].

3. Methodological considerations

Our method is informed by the use of activity theory in applying task analysis for instructional design [9]. Activity theory looks at human activity and in this case teaching and learning activity in context (ibid). In our case, since our data are scenario descriptions and lesson plans for the most part drawn from the web, we analyze the context based on the information provided by the text of the scenario. Using activity theory as a lens to look at the scenario text, we look at the following elements: a) the various activities

included in the scenario (what people do at different stages of the scenario: i.e., micro-activities); b) the tools they use to perform these activities (infrastructure: characteristics, functionalities); c) the actors of the activities (i.e., teachers, students); d) the social relationships of the actors (social orchestration – collaboration) e) the context (grade, type of school, etc.), and f) the goals and intentions (expressed, inferred) underlying these activities. This analysis is then used as a basis to construct recommendations for adaptation of the micro-activity or the scenario. In the work we report here, the recommendations are constructed by domain experts, and as we will show next, these recommendations will be then populated by teacher suggestions with the aim to identify the patterns emerging in the collected body of data. Next in this section we initially applied this frame of analysis on a simple activity (i.e., hanging pictures in the classroom wall), and we used it as a basis to infer the elements for the decision-making system.

3.1 Hanging pictures on the wall: an outsider's view

At first glance hanging pictures on the wall might seem a trivial and rather simple task; or not: "*Now you go and get me my hammer, Will," he would shout; "and you bring me the rule, Tom; and I shall want the step-ladder, and I had better have a kitchen-chair, too; and, Jim! you run round to Mr. Goggles, and tell him, 'Pa's kind regards, and hopes his leg's better; and will he lend him his spirit-level?' And don't you go, Maria, because I shall want somebody to hold me the light; and when the girl comes back, she must go out again for a bit of picture-cord; and Tom!—where's Tom?—Tom, you come here; I shall want you to hand me up the picture*." [10][p 26]. Leaving aside the humorous style of the extract, we realise that the activity of hanging pictures on the wall might involve a task analysis and a rather demanding co-ordination of activities and persons. We use this example to show that in order to respond to the question "Can I do this" we need to start thinking beyond a conventional use of ICT in the classroom and take a creative stance in: a) using technology for teaching and learning and b) exploring the instructional goals that can underline each activity.

To further elaborate this approach, we take the example of hanging pictures on the classroom wall, adopting an outsider's view. Being an outsider (i.e., imagine observing a classroom activity through the window of the class), frees us from accepting contextual assumptions about the instructional goals, and directs us to explore the context by asking a very important question: why are they doing this? The exploration of possible answers to this question allows us to create a "locus of potentiality" populated with various instructional goals behind a single micro-activity, each of which is re-examined in relation to the infrastructure it requires to be achieved. In our example the micro-activity is the following: "The teacher asks the student to put up the picture on the class wall". The necessary infrastructure for this activity is: a) a framed picture, b) a hammer and c) a nail.

Now let's investigate "why they are doing this", i.e., what are the potential instructional goals behind this activity. In a kindergarten class, each pupil is asked to put their picture on the wall for the whole class to see everybody's work. In this context the required infrastructure to perform this activity is shaped as follows: the picture does not need to be framed, pupils can use blue tag to put an unframed picture on the wall, hammer and nail are not necessary.

In a vocational education setting, the goal might be to show what type of hanging is suitable for each type of wall surface. In this case, the absolute specific infrastructure is needed (i.e., framed picture, nail and hammer), since they are essential for achieving the goal of the specific learning activity. A screw and a screwdriver might provide a useful alternative in terms of infrastructure, depending on the type of the wall, or it could be used as a counter-example of what should not be done.

In a high-school classroom, the picture might be needed on the wall in order to analyse its content in a whole class discussion. In this case the goal is to make the picture visible to the whole class for the duration of the specific lesson. To achieve this goal, we might use a stone and a nail, instead of a hammer, a screw and a screwdriver if they are available, blue tag, or a computer and a projector. In this case the nail, hammer and framed picture are not indispensable.

In an exam context, at high school, the picture needs to be put up on the wall in order for the students to analyse it individually responding to one or more test questions. In this case the goal again is to make the picture visible to the whole class for the duration of the exam. All the solutions to replace hammer and nail mentioned in the previous paragraph are applicable here. Furthermore, taking into account the context of the exam, we might prefer to provide students with a printed picture allowing them to observe it closely and to comment on it in order to structure their response to the test. Alternatively, and if students have their computers or mobile phones with them, they could access a common digital picture or slightly different pictures slightly changing the initial scenario. Again, nail, hammer and framed picture are not indispensable.

3.2. Unit of analysis

The unit of our analysis is the "micro-activity". We use the term to refer to student or teacher actions which are described in a lesson plan or a scenario. Micro-activities, involve a targeted action of the teacher or the student(s), refer to or imply a class orchestration (individual work, group work, etc.) with a specific purpose (learning or instructional) and include the use of specific infrastructure. Unlike micro-learning, these activities can be short or long, depending on the role they have in the scenario. Thus, the use of the term "micro" here refers to the break-up of the scenario or lesson plan to its constituent activities: these are small in relation to the original source.

3.3. From Micro-activities to the ontology and the knowledge base

As long as "Can I do this?" refers to whole educational scenaria, answering it remains very complex. By breaking up a scenario into micro-activities we reduce the question to finding equivalent and alternative micro-activities using different ICT infrastructure.
Educational equivalence depends on the exact context and learning goals. A stone can replace the hammer for driving the nail in the wall, except if the purpose of hanging the picture was the very use of the hammer. Another word processor can replace MS Word for writing a text, except if the purpose of writing the text was learning the specific characteristics of MS Word 2016.

We would need to know the educational rational of the micro-activity in order to find proper equivalents using alternative infrastructure. But the educational rational may be hidden and certainly not explicitly stated in an educational scenario. What our system can do is discern patterns of use (instructional approaches) and propose alternatives for the teacher to decide if they are sufficiently suitable substitutes - some may be unacceptable, others may modify the learning results, others may be equivalent, still others may offer something quite different but quite acceptable.

In our approach we collect learning scenarios in a knowledge-base, searchable by teachers to find appropriate learning scenarios. To provide for finding possible adaptions of a desired scenario, supplement scenarios with their corresponding micro-activities and linking the knowledge-base to an ontology providing concepts to describe the following information used to tag micro-activities: Instructional approaches, ICT Infrastructures, and educational functionalities (affordances) of infrastructure.

To populate the knowledge-base and to extract the necessary micro-activities we follow this procedure:

1. **From the scenario abstract micro-activities** ("hang a picture") and related 'infrastructure' (hammer, nail, picture)
2. **Consider diverse possible instructional rationales** of each micro activity (diverse educational contexts): "why would you want students to hang pictures on the wall?"
3. **Analyse functionality/affordances of infrastructure**

- Hammer: can drive nails into walls
- Nail: can hold framed pictures on walls
- Picture on wall: can be seen by whole class

4. **Consider other infrastructure with**

- similar functionality (stone ~ hammer, screw ~ nail) or
- similar result (glue ~ hang, project digital ~ hang physical, directly observe single physical object ~ thru ICT observe digital copies)

Next, we show how we use these steps to analyze an ICT based scenario and we use one of its micro-activities (searching the web) to provide recommendations for equivalent and alternative activities.

4. Searching the web: recommendations for equivalent and alternative activities

The work we report here takes place in context of the Erasmus + Plus project "eSIT4SIP" (**e**mpowering the **S**chool **IT** infrastructures for the implementation of **S**ustainable **I**nstructional **P**atterns, www.esit4sip.eu). Part of the project's outputs is an ontology-based knowledge-base consisting of a large number of scenarios, which are drawn from different repositories on the web. From this knowledge-base we extract the scenario: "How to revive the story" (Authors: Nada Stojičević, Nikola Ćurčin). The scenario is designed for 15-18 year-old students. The subject matter is not mentioned.

4.1 Micro-activities

The micro-activities (coded as MA) extracted from the scenario are the following:

MA1: Prepare a story that triggers student interest about QR codes and animated maps. [Subject: teacher)

MA2: Discuss the story with the students [Subject: teacher and students]

MA3: Create groups of students (different roles: photographers, researchers, coordinators, animators (to create the animated maps), web designers and coordinators) [Subject: teacher and students]

MA4: Taking pictures of selected sites (topics in the original) [Subject: students]

MA5: Collect material [interpretation: information for the sites included in the map] that will be incorporated in the animated map. [Subject: students]

MA6: Create animated maps. [Subject: students]

MA7: Upload the finished materials to the site (Wordpress) [Subject: students]

MA8: create and print QR codes [Subject: students]

MA9: Students present their work [Subject: students]

4.2 Infrastructure

The Infrastructure mentioned in the scenario involves:

- At least 15 computers with internet access
- Mobile phones with cameras and QR code scanner
- Digital photo cameras
- Software: Animaps, Wordpress, Panorama, QR code generator

4.3 Collection of information - Diverse instructional rationales (alternative activities)

For the purposes of this paper we will focus on only one of the above listed micro-activities, the one that involves collection of information (MA5). We choose this activity because it is a common element of a wide variety of scenarios, especially in social sciences and humanities, and because it is part of a new set of skills acknowledged as digital competences [11]. Further, we consider that this micro-activity can be easily adopted and combined with other micro-activities to various educational settings with various infrastructure configurations because of its common use.

The scenario mentions that students collect relevant material to add on the interactive map without specifying the means or the type of the collected information. However, in the introductory story the authors mention the envisaged material to be collected "*In addition to photography, you are reading and explanation of the museum building, center, municipal building, park, church ....*". This information in relation to the fact that students are creating a digital map leads us to understand that it is short pieces of information describing the sites of the map.

The scenario does not explain neither the means (how they will collect information) nor the tools students are going to use for the collection of this information. From this

fact we can make two assumptions a) that the use of web search is so wide spread that it is not necessary to be mentioned and b) that the type of information collected is not that important because the emphasis is on the construction of the map and uploading relevant material (photos and text) on the map. If we accept the first assumption, the infrastructure required for this micro-activity is: Computer lab, computers connected to the internet, browser.

Setting 1- Instructional goal 1: The filter bubble[12] - identify differences between search engines and between devices (owned by different users). The infrastructure mentioned in the micro-activity is the same but the instructional goal involves the development of digital competences. The micro-activity can be implemented at the same age group in the context of IT lessons.

Setting 2 -Instructional goal 2: Seek, evaluate, select and appropriate information from the web. Here the emphasis would be for the students to learn how to refine their keywords (seek information) evaluate the sources of the information provided and appropriate the information they select to their purposes. Same infrastructure, across subject matters, can be implemented with younger audience (age 12-15).

4.4. Functionalities / affordances of infrastructure

Web-search: Find information around a subject using relevant keywords, offer access to various types of information regarding the topic of interest, sort the information found from the most relevant to the less relevant.

4.5. Use of infrastructure with similar functionality or similar result (equivalent activities).

Infrastructure with similar result: Take an interview from someone who has the information or ask the people who live or work next to the sites that are going to be included in the map, to describe the site of interest with a representative phrase for them. The infrastructure needed here is a notebook or a sound recording device.

Infrastructure with similar result 2: The teacher provides each group with print-outs that contain information about the sites they are going to include in their map. Their job is to appropriate this information so as to be interesting for the users of the map and to record it on a piece of paper. Infrastructure: printouts and notepad.

Infrastructure with similar functionality: Students work in groups, each group being responsible for one site of interest, and take some time to think of keywords they could use in order to search information on the web. When they are ready, each group take turns in dictating their keywords to the teacher who types them on his/her laptop and the teams see the results through a video projector. Then the group with the help of the teacher and the other groups, review the results and refine their search if necessary. The teacher goes through the information found (i.e., reading it aloud) and the group responsible for the specific site, takes notes to use them for the construction of information to be included in the map. Alternatively, the teacher can print out the

information for the groups to adapt it for the map. The infrastructure necessary here is one computer connected to the internet, browser, projector.

The analysis of this scenario is used to demonstrate our analytic framework and the production of recommendations (alternative and equivalent activities) by domain experts. We report here work in progress and at this stage, we focus on our approach (theoretical and methodological) to the data (educational scenarios with the use of ICT) and on how we envisage that this analysis will inform the design of an ontology-based decision-making system for the use of educational resources by the teachers.

5. Concluding remarks

In this paper we described our approach in empowering teachers to integrate in their practice available resources (i.e., ICT enhanced scenarios and lessons) by making use of the existing infrastructure in their schools. Our work is informed by two theoretical underpinnings: a) the role of infrastructure in impeding teachers to try innovative educational scenarios in their class and b) the role of the teacher as designer, who does not simply implement existing scenarios but appropriates them developing utilization schemes. In order to facilitate the appropriation process, we break down the educational scenarios in micro-activities each of which is explicitly connected to the infrastructure mentioned or implied in the scenario and to other equivalent solutions. Furthermore, considering that the use of resources is also a creative process enriching and shaping teacher's knowledge, we explore diverse instructional rationales around the use of infrastructure exploring alternative micro-activities. As this is work in progress, we used an example to illustrate the implementation of this analytic framework and to show how this analysis can be used to inform the design of an ontology and a knowledge base supporting a decision-making system for teachers.

The definition of the micro-activities, as explained in the previous sections, and its level of detail is not trivial and should not be seen as a rigid approach. In other words, it is difficult to establish if the decomposition of learning activities in its micro-activities is always done in the same level of detail. Examples, of such discussions can be found in previous research addressing task analysis. We do not intend to re-open such topic and our present approach is very much aware of the challenge concerning the finding of the appropriate level of detail, especially when connecting the micro-activities with learning goals. However, our decision of creating an ontology to enable the knowledge-base demanded the analysis of the learning scenarios.

At the moment our approach regarding the micro-activities is very much based on examples, self-explanatory examples as much as possible (hence no claims are being made regarding the correct level of analysis). The connection of the micro-activities with the ontology is based on the assumption that the latter must be structured in such a way that allows expansion and revision if need be. Furthermore, although we assume a mapping between the description of the micro-activities with the elements of the ontology, the terms do not need to be the same. This issue is important since it considers the long-term goal of creating a sustainable system, where teachers and other stakeholders can contribute to the analysis of the learning scenarios, describe the micro-activities and facilitate its refining and extension.

The knowledge-base will support teachers deciding if a particular learning scenario can be effectively enacted in their specific context. It will do so by providing alternatives regarding the technologies in use and suggesting learning activities that take advantage of the existing technological infrastructure in a school. Additionally, we expect to create a vibrant community with teachers and other stakeholders actively sharing learning scenarios, providing advice regarding the implementation of the different scenarios, or even suggesting alterations based on their own experiences.

Moreover, as mentioned in the previous section, teacher and other stakeholders should be able to provide the analysis of scenarios based on micro-activities as well as contribute to the refining and extending of the ontology. The way to implement this collaborative process of refining and extending the ontology is still an open topic. We can envision a functionality where teachers choose terms to express the micro-activities of their scenarios and connect them with instructional goals and infrastructure. Whenever the analysis of the scenarios demand terms/categories not yet available, expert members of the community receive requests for extending the ontology with corresponding terms/categories and do so accordingly. This process might be particularly important in the early stages of deployment but we expect that it should stabilize in the long-term, in other words, the ontology will not grow indefinitely.

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