Engaging students as designers of digital curriculum resources: focus on their praxeologies and new awareness

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In this paper we present the results of a pilot study focused on an educational programme aimed at involving upper secondary students in the design of digital curriculum resources (DCR) using the GeoGebra software. We analyse the reflections proposed by the students-designers during semi-structured interviews developed at the end of the educational programme. As a result of this analysis, we propose a characterization of students-designers' praxeologies in relation to the task of DCR-design. This characterization highlights their awareness both on the characteristics of the DCR that supports students' learning and on the role of the design process in fostering the designers' learning.

Keywords: Digital curriculum resources, students-designers, praxeologies, awareness.

Introduction

In the last decade an increasing interest in studying the role played by digital tools in supporting the process of task-design has emerged (see, for instance, Leung & Baccaglini-Frank, 2017). Here, we focus on digital curriculum resource-design to broaden the set of possible products of the design-process: not only tasks, but also revision guides for specific topics, digital materials to introduce new mathematical topics, interactive e-books. We refer to Pepin et al.'s (2017) definition of digital curriculum resources (DCR) as "organised systems of digital resources in electronic formats that articulate a scope and sequence of curricular content" (p.3).

Many studies in mathematics education have been focused on the effects of involving teachers in the process of task/resource-design on both their professional development and the effectiveness of the designed instructional materials (Jones & Pepin, 2016). Few studies have, instead, focused on students as co-designers (Diamantidis, Kynigos & Papadopoulos, 2019) or designers of digital tasks/resources (Alessio et al., 2021). Our research is set in this mainstream of studies. In this paper, we present the results from a pilot study aimed at involving upper secondary school students as designers of DCR.

Theoretical framework

The first component of our theoretical framework, the tetrahedron model (Albano, Faggiano & Rossi, 2018), is considered to interpret the dynamics that characterize the process of DCR-design. This model takes into account the relationships between the Teacher (T), the Student (S), the Mathematics (M) and the Designer (D) of digital materials, and considers technology as a mediatory sphere embedded in the tetrahedron with vertices T, S, M and D.

The second component of our theoretical framework is introduced to analyse how the process of DCR-design affect students' development of specific competencies and awareness about their learning. The design of DCR could be conceived, in fact, as a specific task for students. For this reason, a product of the process of DCR-design is the students' development of specific praxeologies associated to this task. The notion of praxeology has been introduced by Chevallard (1991). It could be structured in two main levels (García et al., 2006): the *know-how level*, which includes the task, or a family of tasks, and the techniques used to face the task; the *knowledge level*, which includes the "discourses" developed to justify or frame the techniques for the task. The discourses on the techniques, as stressed by Artigue (2002), could focus on both their *pragmatic* value, connected to their productive potential in terms of efficiency, costs, validity, and on their *epistemic* value, more difficult to be grasped, connected to the way in which the techniques could contribute to the understanding of the objects they involve.

Context of the study

The students involved in our study (7 upper secondary school students, grade 12) participated to an educational programme set up by the Department of Industrial Engineering and Mathematics of the University of Ancona. The programme, aimed at supporting the transition from secondary school to university, was articulated in 10 meetings (50 hours in total) during which participants have been guided in deepening their knowledge of specific mathematical topics through the use of GeoGebra as a tool for DCR-design. The first 2 meetings were devoted to introducing mathematical topics that participants had not faced at school, namely complex numbers and limits. The introduction of these topics was supported through the use and analysis of specific applets aiming at different goals (explanation, exploration, visualization, remediation, self-assessment). In this way, students experienced specific functionalities of the GeoGebra software, such as check boxes, input fields, sliders, drag and drop. In this initial phase, in order to make participants become familiar with the software, they were also guided in the creation of their first GeoGebra applet concerning the exploration of the function y=sin(x).

In the second phase (8 meetings), participants (in the following, SDs, acronym for students-designers) were asked to design and implement DCR through the creation of GeoGebra applets, choosing the mathematical topic on which they preferred to focus. SDs, who worked in small groups, were suggested to consider the difficulties students could face and to exploit the potentialities of the software to create DCR aimed at supporting them in overcoming these difficulties. This activity, which was the central one in the educational programme, was carried out in presence of tutors (university researchers), available to provide SDs with technical hints concerning software aspects, if necessary. Specific criteria for the DCR-design were not shared with SDs in order to enable them to identify their own criteria.

If we refer to the tetrahedron model to interpret SDs' activity within our educational programme, we can highlight specific new dynamics. In fact, while, usually, students are located in the S vertex of the tetrahedron and are mainly involved in the dynamics that characterize the S-M-T or S-M-D faces, in our programme students are located at the D vertex (as SDs) and the focus is on the D-M-T face. T represents the tutors, who has assigned to D the task of designing DCR, using digital tools to support the learning of the mathematical content M. Since the resource produced at the end of DCR-design will be, in turn, a task for other students, the meta-reflections developed by the students-designers enable them to become strongly involved also in the interactions that characterize the S-M-D face of the same tetrahedron (where S represents the hypothetical students for whom the DCR are designed).

Research aims and methodology

The main aims of this research are: (1) to characterize the praxeologies, developed by the SDs involved in our study, in relation to the task of DCR-design using the GeoGebra software; (2) to investigate how SDs interpret their experience of being both students and designers.

The data collected were: (a) the digital resources designed by SDs, (b) SDs' answers to a final written questionnaire on the process of DCR-design, and (c) a final audio-recorded semi-structured interview.

In this paper, we focus on the analysis of SDs' interviews. To characterize their praxeologies (first research aim), during the interviews, SDs were asked to describe the process of DCR-design (know-how level) and to justify the choices they made during this process (know-why level). In particular, they were asked to justify their choices by focusing on: the didactical objectives of their DCR (to review a topic, to assess students, to support recovering…); the potentialities and constraints of the GeoGebra software as a tool to support the design of their DCR (pragmatic value of the adopted techniques); the difficulties related to the mathematical content on which the DCR is focused and the ways in which the DCR-design could support the students' learning of this content (epistemic value of the adopted techniques). To investigate SDs' interpretation of their experience of being both students and designers, at the end of the interviews, they were also asked to assess their experience, by reflecting on its usefulness (or not).

The transcripts from the interviews were coded independently by the two authors, who identified specific excerpts useful to characterize both the know-how and know-why levels of SDs' praxeologies (research aim 1) and the ways in which SDs interpret their experience (research aim 2). Afterwards, codes were discussed in order to come to agreement.

Data Analysis

Characterization of students-designers' praxeologies related to DCR-design

Because of space limitations, we will focus on two SDs – Marco and Anna – and on their discourses about their design of a specific kind of DCR: a revision guide for a mathematical topic. We chose to compare the praxeologies of these two SDs because of their different previous experiences with GeoGebra and the different choices they made in relation to the mathematical topic on which to focus in the DCR-design. Anna had never used GeoGebra previously at school, while Marco attends to a school focused on digital technologies' use. Moreover, while Anna chose to focus on a mathematical content she already studied at school (goniometric inequalities), Marco chose a topic he studied for the first time within the educational programme (the comparison of infinities). During the interviews, Anna and Marco effectively re-construct their design, enabling us to characterize their praxeologies, related to the *common task* of designing DCR to support students in the revision of specific mathematical contents. Here we focus on common elements of these praxeologies.

In the excerpt of Anna's interview on which we focus here, she reconstructs the design of a DCR aimed at supporting students' revision of goniometric inequalities. In particular, the applet she created

(Figures 1A and 1B) is aimed at making students reflect on different possible representations of the solutions of the inequalities $cosx > a$ and $cosx < a$.

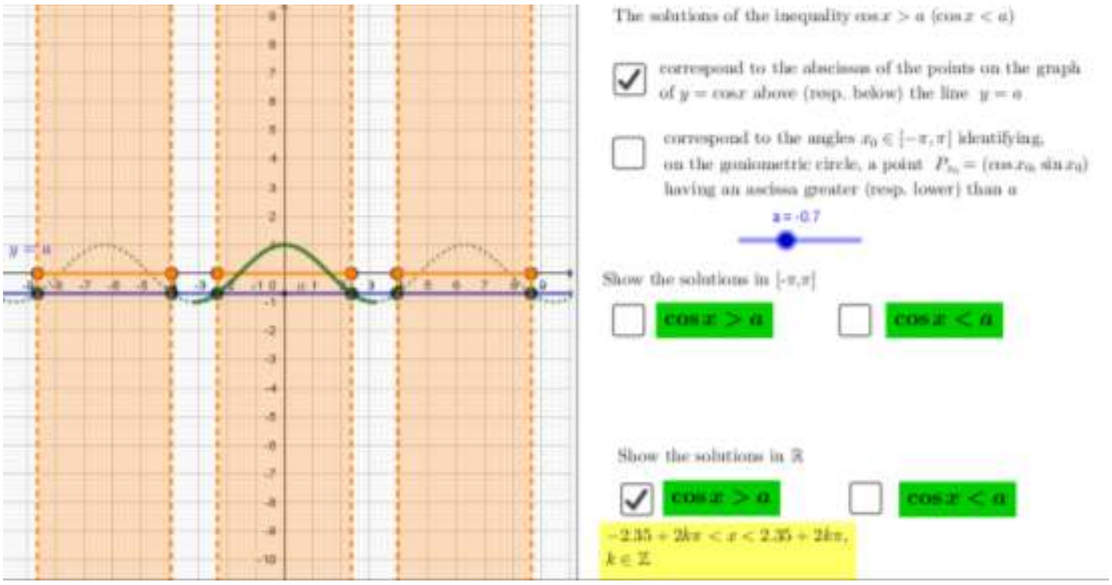

Figure 1A: The DCR on which Anna's interview is focused; the solutions of a goniometric inequality are represented as abscissas of points on the graph of the goniometric function $y = cos\ x$

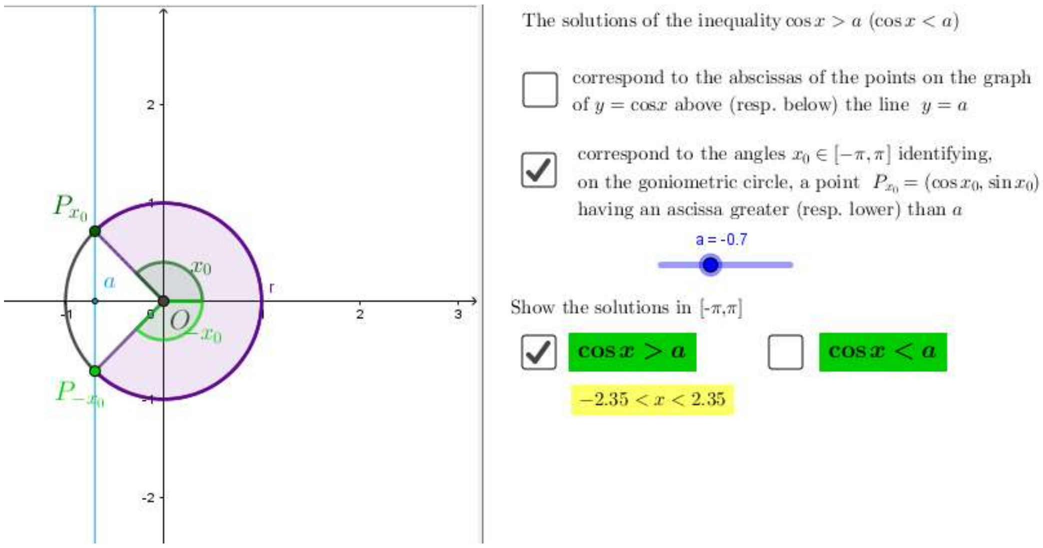

Figure 1B: The DCR on which Anna's interview is focused; the solutions of a goniometric inequality are represented as points on the goniometric circle corresponding to specific angles

In his interview, Marco focuses on his design of a DCR to support students' revision of the comparison of infinities in the study of limits. He created an applet (Figure 2) aimed at making students graphically compare the "ways" in which the functions $y = \log_a x$, $y = x^p$, $y = a^x$ and $y = x^x$ tend to infinity when the x variable tend to + infinity.

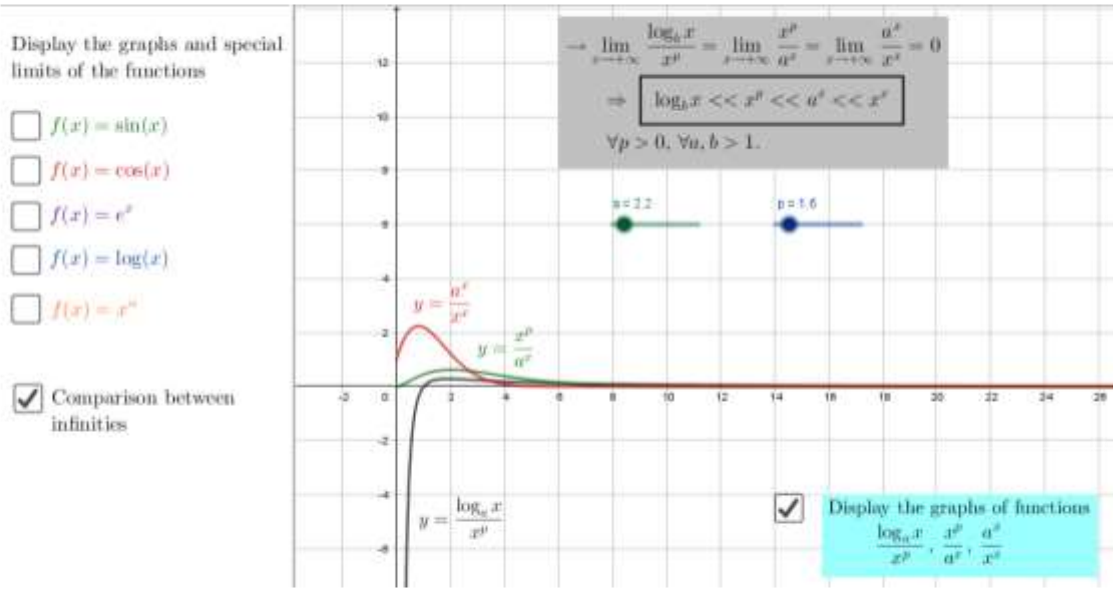

Figure 2: The DCR on which Marco's interview is focused

Even if they focused on different mathematical topics, the two students adopted similar *techniques* (*know-how level*) to face the task of creating revision guides. In their reflections, in fact, they stress on the importance of creating digital resources that enable students to: (a) choose the objects to display on their screens (different kinds of representations, graphs of specific functions, symbolic formulas…) and the order in which these objects are displayed; (b) see multiple representations at the same time and interact with them; (c) observe the effects of the variation and covarion of specific parameters using the sliders.

The use of these techniques is evident in both the DCR designed by Anna and Marco. Both students explicitly refer to these techniques in their interviews. For example, referring to *techniques (a) and (b)*, Anna declares that she has designed her DCR to enable students to choose the representation of the solutions of a goniometric inequality and also whether visualizing these solutions only in a range or across the whole set of real numbers (as in the Figures 1A and 1B). Marco refers to the same techniques when he stresses that, thanks to the design of his DCR, students can display different graphs at the same time and choose if visualizing the graphs of the functions $y = \log_a x$, $y = x^p$, $y = a^x$ and $y = x^x$ or the graphs of their ratios, that is of the functions $y = \frac{\log_a x}{x^p}$, $y = \frac{x^p}{a^x}$, $y = \frac{a^x}{x^x}$.

Both Anna and Marco inserted sliders in their DCR (*technique c*). Anna inserted a slider to enable students to explore different possible situations, according to the value of a within $cosx > a$ and $cosx < a$. Marco inserted two different sliders to enable students to visualize how the graphs of the functions dynamically vary according to the values of the parameters *a* and *p*.

When they justify these techniques (*knowledge level*), Anna and Marco focus both on the description of practical aspects connected to the DCR-design process (*pragmatic* aspects) and to the reflection on how these techniques could contribute in creating DCR that really support students in the learning process (*epistemic* aspects).

Both Anna and Marco stress that making students choose what to display (*technique a*) enables them to manage the information on which to focus. Anna, for example, focuses on pragmatic aspects when she declares:

> "[*this applet*] enables students to make graphs appear and disappear when they want, instead of visualizing them all together. In this way, there are not too many information, but only the information I require, so I can manage them".

In relation to the possibility of deciding the order in which to display information, she adds a reflection that shifts the focus on epistemic aspects, connecting the chosen technique to difficulties she experienced when studying goniometric inequalities:

> "It seems better to focus first on [*the solutions in*] an interval, so as to gradually introduce the periodicity. In the classroom, also, one of the main difficulties is to write the solutions with periodicity".

Marco also reflects on the epistemic value of technique *a*, when he explains how the teacher could use the DCR he created:

> "This exploits the potentialities of the software; [*the DCR*] has been designed for didactic purposes: [*the teacher*] shows the file and can show, for example, the cosine function first, then the parabola and this allows to give a further meaning to the concept of limit; the software allows you to show these things in the order you prefer and then allows you to explain".

Anna and Marco focus also on the potentialities related to making students work with multiple representations (*technique b*). Anna, for example, declares that her choice to adopt technique *b* in the design of her DCR was aimed "to give, to the users, the possibility to display all the representations of the solutions of goniometric inequalities". While Anna's reflection mainly refers to the pragmatic value of technique b, Marco focuses on the epistemic value of the same technique, by stressing that making students work with different representations enable them to give different meanings to mathematical concepts: "Give a new meaning, seeing limits, truly see them! It is something that this software enables to do."

When reflecting on *technique c*, Marco focuses on the role played by sliders as tools that support students' understanding, by enabling them to work with dynamical figures (pragmatic level) that represent classes of mathematical objects (epistemic level):

> "There are [*in my DCR*] classes of functions depending on sliders. This applet has been conceived with a didactical aim, so that a student who faces this topic for the first time, playing with sliders, can see how limits and classes of infinities change. It seems to me that it is like 'putting your hands in it', something more than seeing it in a 'sterile' way, within a textbook. This [*technique*] enables [*students*] to better understand what they see".

Anna justifies her choice of inserting a slider in her DCR by focusing on both pragmatic and epistemic aspects, since she observes that using sliders, differently from working with paper and pencil, enables students explore a wide range of possible situations (pragmatic level), interacting, at the same time, with different problems belonging to the same class of problems (epistemic level):

> "For the user, the sliders offer the opportunity to visualize and try different possibilities also in various points of the circumference and of the graph; if I had done it on a sheet [*paper and pencil*], I would have assigned a unique value to a [*the parameter in the inequality* $cos x > a$], so there would have been less chance of comparison."

SDs' interpretation of their experience as both students and designers

When Anna and Marco are asked to assess their experience as designers of DCR, they both interpret the DCR-design as a particular problem-solving activity that enables the designer to reflect on aspects that usually are taken for granted. In this way, they highlight to be aware that the meta-reflections on the interactions that characterize the S-M-D face of the tetrahedron, which they developed thanks to the experience of DCR-design, have influenced their relationship, as students, with the mathematical content at stake. According to them, these meta-reflections gave to the designer the opportunity to autonomously discover, while facing the difficulties connected to the design process, key-aspects of knowledge construction. Marco, for example, declares:

> "It has been instructive, for me, to create tasks on these topics. In creating tasks, I learnt these topics. It has been a sort of problem solving where the problem is to create a problem. … At a didactical level, this work [*the DCR-design*] was very useful: putting your hands inside it, having to think about tasks … it seems to me that it is one of the best ways of learning a topic."

Thanks to their reflections on the dynamics characterizing the S-M-D face of the tetrahedron, Anna and Marco also have the opportunity to compare their experience as SDs with previous experiences as students. In particular, they contrast their learning through DCR-design, described as a "learning by discovery", with the learning realized through textbooks, described as a "pre-packaged learning", as testified by this reflection, proposed by Anna:

> "Creating resources from scratch was a completely new experience for me; I was used to textbooks, where exercises, and also theory, were ready-made. I found myself 'at the opposite side' with respect to those who study. It represented for me a new and more complete form of revising [*contents*]".

Final discussion

In this paper we have analysed the process of DCR-design in which a group of secondary school students have been involved during an educational programme carried out within a university context. The analysis we have performed, focusing on the reflections developed by SDs during the semi-structured interviews we carried out, has enabled us to reflect on the effects of DCR-design at two levels: (1) the level of students as designers; (2) the level of students as learners.

As regards level (1), the investigation of SDs' praxeologies has highlighted their capability of justifying their choice of adopting specific techniques in their DCR-design by clearly referring to both the efficiency of these techniques with respect to those adopted within a paper and pencil environment (*pragmatic value*) and the learning that each technique could support (*epistemic value*).

As regards level (2), the semi-structured interviews we have conducted have boosted SDs' reflections on the ways in which acting as designers could support the designers' learning itself, showing the effectiveness of activities aimed at fostering students' reflections on the dynamics that characterize the S-M-D face of the tetrahedron.

As a further development of this research, we are deepening our investigation of SDs' praxeologies related to DCR-design by combining the analysis of a-posteriori interviews with the audio and video-recording of the DCR-design process. We are also working on the re-design of the teaching methodology that characterized the educational programme to promote opportunities for SDs to share their reflections about their double role of designers and learners with their school mates, involving also their teachers in this process.

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