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Sculpture Development as an Informal Activity for Learning Engineering Abilities in K-12 Students*

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The social changes that have taken place in recent decades have determined the evolution of the educational system. Society nowadays demands new learning methods, focused on an appropriate selection and processing of information instead of memorization. The rise of the Information Technologies has led to different "Emergent Pedagogies". One of them is Informal Learning, which proposes shifting the generation and acquisition of knowledge from the individual to the collective plane.

The present research expects to raise K-12 students' interest in engineering by adopting some methods that are typical of informal learning in the field of formal learning. The objective is to stimulate the group learning processes for the generation of collective knowledge through multidisciplinary team interaction and dialogue. For this purpose, a group of 25 K-12 students organized in subgroups carried out a co-creative project. This project consists in the development of a sculptural assembly made of glazed ceramics over a steel structure, which will be installed in the educational centre. A concurrent project methodology was used to create the sculptural assembly. Here, each student must perform different tasks related to design engineering. An educational model based on Blended Learning was used, which proposes the combination of in-person sessions with virtual work by means of social networks as a group communication medium. Thus, each creative team member contributed with their own Personal Learning Environment in order to enrich the group learning process and provide it with their own personal singularities, thereby turning it into a Personal Learning Network.

The experience allowed K-12 students to discover the working process typical of design engineering through a recreational methodology based on Informal Learning. The students were able to make up for their shortcomings in terms of technical and creative skill, while becoming aware of their chances within the field of engineering. The project has been shown to be an incentive for K-12 students regarding their interest in starting engineering studies once they finish their K-12 stage.

Keywords: informal learning; K-12; engineering project; collaborative design; b-learning; PLE; social networking

1. Introduction

The bases of the current Educational System were established in the period of the Industrial Revolution. That system was created under the concept of the society of that moment, in which the only method of knowledge transmission was repetition and memorizing contents, and where access to information was restricted to only a few. Nonetheless, today's society has made access to information widely available and there is widespread demand for new learning processes based on new principles like the selection and processing of information through reflection and interaction between people [1]. All this process of change has been possible thanks to the Information Technologies (IT), which make new modes of interaction possible, and users are converted into creators, consumers and content editors. This opens up the way to what is known as the Emergent Pedagogies [2].

The Social Constructivism theory of Lev Vygotsky, which has supported educational systems for decades, bases the construction of knowledge on the personal experience of each individual when relating with his environment. Consequently, he builds his own mental schemata of knowledge [3]. Nonetheless, this theory fails to take into account the learning that happens outside persons. Starting out from Chaos Theory, Siemens defended that the new knowledge theories point out that meaning is there, and the challenge of the apprentice is to recognize the patterns that seem to be hidden. This fact makes the formation of connections between specialized communities gain in relevance. Connectivism Theory arises from these concepts. This theory understands that knowledge can exist outside individuals, and it focuses on connecting sets of specialized information. So, it becomes more important to establish good connections than our current level of knowledge [4]. In this same line, Dialogic Learning is focused on collaborative learning based on human interaction through dialogue—in all its dimensions—and the permanent generation of interpersonal connections [5].

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Informal Learning is one of the Emergent Pedagogies. It was introduced in 1938 by Dewey, who considers that experience comes from interaction and continuity [6]. Here, continuity is understood as referring to each of the individual's experiences that will influence his future, while interaction is related to the influence of the situation in the experience of the individual. Baser et al. [7] define Informal Learning as a continuous learning process that happens throughout life. Usually, traditional learning, known as Formal Learning, is given in an institutional setting—school, courses, classrooms and workshops. Nevertheless, people spend most of the time outside this setting. Informal Learning happens in this "outside" context in a more spontaneous and relaxed way by means of mechanisms such as trial-and-error, asking a neighbour, conversing with others, taking part in a group, etc. Therefore, Informal Learning tries to move the knowledge acquisition and generation from the individual to the collective field [8].

Dorie et al. proposed a taxonomy on Formal and Informal Learning Environments (FILE), consisting in four different scales of learning evidenced in both formal and informal environments: self-directed/collaborative, active/passive, learner-/goal-oriented, and mandatory/voluntary [9]. Baser et al. proposed the use of Informal Learning in the engineering field as a way to achieve knowledge acquisition through personal experimentation within team work. Khaddage et al. recommended using Mobile Apps Technologies to create informal and formal learning environments, thus promoting creativity, interactivity and game-based learning environments [10]. García Peñalvo et al. [11] showed five works in which different conceptions of Informal Learning are presented regarding the Web 2.0 philosophy.

In the Spanish educational system, there is an optional pre-university stage of studies that comprises students between 16 and 18 years old (K11 and K12). The Spanish organic law on education [12] defines three modalities for this stage: arts; science and technology; and humanities and social sciences. Each modality is composed of a set of common subjects, modality subjects and optional subjects. As K11 and K12 students are in the stage prior to university studies, their studies must also awaken their interest in one of the professional branches or disciplines that will motivate their selection of a certain university degree rather than another. For this reason, it becomes necessary to develop activities in this K-12 stage that are capable of awakening students' vocational interest, in addition to providing them with notions of engineering.

Design Engineering is a specific case within engineering, since it merges two different but closely related professional profiles: technological and creative. It is necessary to have engineering knowledge on materials, mechanical systems, industrial processes and technologies, and CAD/CAM/CAE tools. But it is also necessary to know about aesthetics, conceptual design, artistic expression, graphical design, or model and prototype development. The merging of all these disciplines provides design engineers with the required competences so as to be able to deal with projects involving new product designs and development. Generally, the students that start design engineering at the Universitat Jaume I of Castellón in Spain [13] come from the technical branch of K-12 studies. So, they have a strong technical profile [14], which provides them with a good basis for technical subjects, but they have several shortcomings in the creative subjects. And it has been defended that both skills are needed in the design discipline [15]. This makes it interesting to encourage students from the artistic K-12 branch to choose design engineering studies, since they have studied subjects related to volume, artistic drawing, graphic and plastic expression techniques, etc. It is important to eliminate the fears they may have about technical subjects, like physics and mathematics, since they are not a real disadvantage for them.

The aim of achieving a double profile (technical and artistic) of incoming university students is to be able to form multidisciplinary teams with the capacity to collaborate in new product design and development projects. This is supposed to be a similar way of working to that they will find in the labour world [16]. It is thus possible to enrich the learning processes based on the group development of creative projects. Learning to work in multidisciplinary teams is fundamental in any discipline related to design. Consequently, it is possible to optimize the efficacy of the available resources, both human and material, by reaching agreements and tackling them from a proactive position. For this reason, it is interesting to carry out activities addressed to K-12 students from both the technological and artistic branches, with the aim of encouraging the choice of engineering studies.

The purpose of the present research is to increase the interest of K-12 students in engineering, and more specifically design engineering. An experiment was developed for this purpose. Here, several competences related with engineering were worked on in order to show students their capacity to deal with these university studies successfully, regardless of their K-12 background. Some methodologies typical of Informal Learning were used in a Formal Learning setting in order to stimulate the group learning processes for collective knowledge generation through interaction and dialogue. Moreover, an attempt is made to motivate students to discover the engineering processes and modes of working by carrying out a "recreational" project that allows a relaxed learning environment to be created. The study connects to the current STEAM movement in the US, integrating arts into the STEM fields, seeking to incorporate divergent thinkers in teamwork full of convergent thinkers, who march straight ahead towards their goal [17, 18].

2. Designing the activity

The present study proposes the use of Informal Learning activities to develop specific competences in K-12 students that are essential in the field of Engineering Design. The aim of performing activities with a recreational approach is to awaken the interest of the students in engineering by removing the initial fears that students may have about their shortcomings, both in technical and artistic competences. The aim of the study is to increase the engineering abilities of students through an experimental study. It is also pretended to encourage them to access to a university degree of engineering. In this way, the outcomes expected are the achievement of a satisfactory level in each of the engineering abilities developed in the proposed activity.

Different processes of evaluation have been used with the aim of assess the level of achievement of the different objectives, both at individual level and the teamwork. In this line, we found the work of Martinez et al. [19], who presents a study on the use of different assessment tools used for evaluate the results of different type of sessions. In the same way, it has been evaluated the project development and the methodology employed, with the aim of assess the satisfaction grade of the students and, consequently, their interest in engineering degrees.

2.1 Work context

The research was conducted throughout the last term of the school year 2010/11 in a High School in Castellón de la Plana (Spain). This is a public centre in which all modalities of K-11 and K-12 studies are given, in accordance with the Spanish educational curriculum [12].

Twenty-five students from the first year of the artistic baccalaureate (K-11) were selected for this study. Most of those in the sample were between 16 and 17 years old, but there were also a few 18 or 19 year olds. K-12 students were not considered because they are engaged in the final process of preparation for the university entrance tests. Similarly, younger students were dismissed because their level of maturity may be unsuitable for the magnitude of the project. The sample size was considered adequate, since it is big enough to carry out a co-creation project, and it is not too large for the facilities available at the centre. The experiment was carried out in 32 one-hour in-person classes distributed over 11 school weeks, and 25 hours of work to be done outside school time.

In order to endow the activity with a more informal look, the 10th anniversary of the educational centre was used as inspiration for the work. Accordingly, students were asked to come up with a commemorative sculptural assembly that will be placed permanently within the school premises. The aim of this selection was to carry out a project of a considerable magnitude, which allowed for collaborative work among all the participants [20]. Moreover, the intention was to endow the project with a social repercussion in order to motivate the students, since the result would be put on public display in front of their schoolmates and neighbours.

The case study was carried out in a ceramics cultural context, involving both industrial and artistic aspects. The ceramic cluster in the region of Castellón embraces 90% of the Spanish ceramic businesses, and its origins date back to the 18th century [21]. Therefore, this material was selected to produce the sculptural assembly. Artistic ceramics, as a discipline, has a strong technical component centred on knowledge about the physical and chemical characteristics of different materials. Furthermore, these materials undergo important transformations during the firing process that will condition the design decisions made during the conceptual phase, as well as during the processes of moulding and manufacturing the pieces. Glass ceramics also add a wide range of specific materials used for the formulation of vitreous compositions for decorating each of the pieces. On the other hand, this material also has a strong artistic component. It is an ancestral material with a huge expressive potential, capable of communicating ideas and feelings through its form, texture, colour or surface finish. The process of modelling each piece was perceived by the students as recreational, as they declared at the end of the project. Hence, the material was seen as appropriate for carrying out the project within an Informal Learning work environment.

2.2 Methodologies

The sculptural assembly was developed using a project methodology from concurrent design [22]. The students had to simultaneously carry out different work processes typical of Design Engineering. Moreover, a collaborative work methodology was used to co-create the sculptural assembly [23]. Sanders and Simon defined co-creation as "one act of collective creation which is experienced by two or more persons in a collaborative manner". They distinguished different kinds of co-creation within a community or enterprise, or between enterprises and another implied agent [24]. The goal is to accomplish a methodology of Collaborative Learning. Johnson et al. defined Collaborative Learning as "the set of methods and instructions to be applied into small groups, of training and development of mixed abilities (learning and social and personal development), in which each group member is responsible for his learning as well as the learning of the rest of the group members" [25]. Each team member contributed with their Personal Learning Environment (PLE). This enriches the group learning process and provides personal singularities. Norman synthesized the PLE process by putting the user at one extreme and the people with whom the knowledge and information is to be shared at the other extreme. Between them, there are the different communication tools, which are used as the channel for knowledge transmission [26]. The sum of the PLE of all the members of the creative team becomes a knowledge connection network where contents and information are shared. This is known as a Personal Learning Network (PLN) [27].

A Blended Learning—or b-Learning—educational model was used. Such models propose the use of in-person work sessions in combination with virtual work. Carman established the key elements for b-Learning to exist, namely, in-person sessions, on-line content, collaboration, evaluation, and support material [28]. Allen and Seaman set a rate of 30% to 79% as the percentage of on-line content for a learning process to be considered b-Learning [29].

2.3 Communication management

Social Networks were used as a communication method for connecting the PLE of the different creative team members in order to carry out the virtual work. Social Networks are based on non-hierarchical and open communities. Users are linked by a common topic and a web platform so they can operate content, construction and collaboration in an intuitive and easy way [30]. Social Networks, as a cloud service, create and promote interactions between people. They have brought about an extraordinary amount of progress in human interaction and communication [31] and this advancement is extremely useful in the educational field. Sarka et al. presented a study on the use of Social Media in Engineering Design [32], showing the interest and usefulness of this kind of systems in the professional field of Engineering Design.

There are specific tools for the management of engineering design projects, such as PDM/PLM. However, they can be complex for K-12 students. For this reason—and within the scope of informal learning—it was decided to use the social networks for this purpose. Social networks allow effective communication between a large group of people and students are already very familiar with them, so they can be assumed to be appealing as a recreational device with which to get them interested in the project. In the present research, Facebook (www.facebook.com) was used, since it is the best-known social network among the students, and it also offers the features required to manage a creative project such as the one proposed here [33]. Nonetheless, each student created a specific profile for the project, in order not to invade the privacy of their personal profiles, since most of them are under age.

2.4 Organization of the teamwork

Teamwork was organized into five subgroups. Different organizational roles were distributed inside each subgroup, while maintaining a non-hierarchical distribution in which all members were responsible for all the work carried out, even if they had not participated in them explicitly. All information regarding the project was centralized on Facebook in order to make this possible. Therefore, all students had access to the same information at any time. Consequently, all the students had the capacity to make decisions as well as access to the information needed to assess the alternatives put forward in each case.

Each subgroup created a Facebook group, in which the teacher was also included to act as a coordinator of the project. All publications related to the work of the subgroup and its members were carried out inside the Facebook group. There were debates about individual creative proposals and decisions were made, such as the selection of the location or the design of the column. Notifications from the teacher to the students were communicated through the internal mail of Facebook. Communication from a student to the teacher—who is acting as a technical advisor—was carried out by different means, such as postings on the teacher's wall, the internal mail or even instant messaging provided by the Social Network. Facebook allowed for the conceptual development of the different proposals developed by each subgroup in a collaborative way. Threads were created from images of sketches, which allowed group members to select them and to refine the design of each part of the sculpture until a detailed design was accomplished.

Once a consensus on the final design had been reached for each column, scale models of each of them were produced with the aim of studying the volumes in detail, together with their complexity and their technical viability regarding the restrictions of ceramic materials. From these scale models, a virtual 3D model was developed using the Solid-

Works software tool, which is commonly used in the field of product engineering (www.solidworks.es/). Since the five columns form a single sculptural assembly, the assemblies of the different columns were made from the virtual modelling of each piece in order to assess their formal coherence. Finally, the standardized manufacturing plans of each of the 41 parts that make up the sculpture were drafted, and subsequently the manufacturing process of each piece was studied taking into account the particularities of ceramics.

It was necessary to manufacture tooling for the construction of some of the parts and so the students had to either design and manufacture or purchase them. Specifically, two manual rolling mills, several templates for the development of some revolution parts or running moulds for rounding edges were manufactured. In addition, some hemispherical casts made of expanded polystyrene were used to facilitate the modelling of certain parts. It was also necessary to develop custom-made tooling for the internal organization of the kiln furniture, consisting of tungsten carbide grooved kiln shelves and mullite tubular props. The internal volume of each kiln was analysed in order to adapt the measures of the different components that were required. A process of firing a set of Orton pyrometric cones (www.ortonceramic.com) was needed in order to test the maximum temperature of each kiln.

Each student carried out individual tasks (like conceptual design proposals or information research), group tasks within their subgroup (like 3D virtual modelling of one column, construction of a piece or tooling design and manufacture) or group tasks done by the creative team as a whole (like measurement of the linear contraction of the ceramic plaster, the creation of the colour palette with the materials available or the proposals for the location of the sculpture).

2.4.1 In-person work

Some of these tasks were conducted in-person; these were usually those related to the use of materials and the construction of parts or pieces. All of them were performed in the educational centre during school hours set aside for the course. These tasks were:

- *Development of a palette of 90 colours (Fig. 1):* Development and indexing of test pieces, composition of coat glaze [33], decoration of test pieces, etc.
- *Measurement of the linear contraction (%LC) of 3 ceramic clays:* Production and indexing of test pieces; measurement of green, dry and fired test pieces; calculation of the % of LC [34].
- *Construction of the 41 pieces that make up the sculpture (Fig. 2):* Different modelling and construction processes; drying; bisque firing; decorating with coats of ceramic glazes and natural oxides; firing [35].
- *Assembly of the pieces in 5 columns:* Organization and distribution of the pieces, attaching them to the steel structure.
- *Installation of the sculpture:* Distribution of the columns in their final site, creation of the concrete footing and fixing each column.

2.4.2 Virtual work

The tasks carried out in a non in-person way were focused mainly on individual actions, which were subsequently contributed to the subgroup or the working group. These tasks were:

- *Documentary search and information processing:* Artistic references, construction techniques and materials, use of design tools and 3D modelling, etc.
- *Development of individual products that have subsequently been contributed to the subgroup:*

Fig. 1. Colour palette.

Fig. 2. Modelling of a piece.

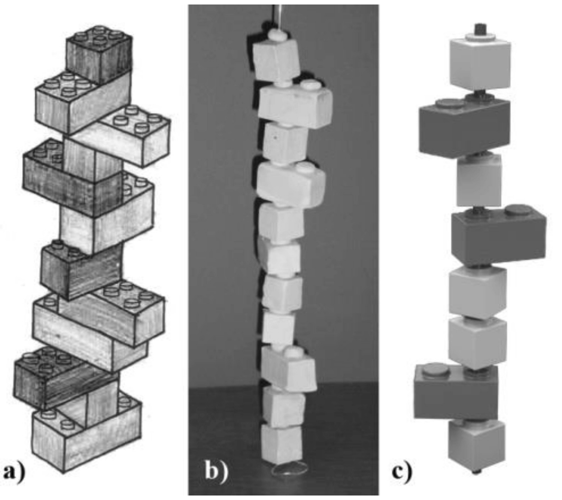

Fig. 3. (a) Initial sketch; (b) Scaled model; (c) 3D rendering.

Sketches, models, tooling, proposals for location, etc. (Fig. 3).

- *Publication of content through social networks:* Images, photographs, videos, text documents, presentations, etc.
- *Participation in debates:* Critical comments on the contributions of colleagues or their own inputs.
- *Participation in decision-making:* Voting and making comments.
- *Performing documentary research regarding the work processes used and the results achieved:* documents, photos, videos, presentations, etc.

3. Development of engineering abilities

The project allowed students to develop different technical and creative aspects that are required in the field of Engineering Design. The aim of this was to present the students with the wide range of disciplines involved in this type of studies, in an attempt to awaken future vocations among them.

3.1 Organization of the teamwork

The 25 students were organized into five autonomous subgroups with five members in each one [37]. They were distributed according to their affinities and interests when working together as a team. Within each subgroup, the members assigned themselves different organizational roles. Accordingly, they had to assume the responsibilities corresponding to each role: leadership, organization of human resources, representing the interests of the subgroup, etc. However, all the members of each subgroup assumed full responsibility for the tasks performed by it. By doing so, they had to rely on the work of their teammates and accept supervision.

In addition, the students had to relocate their organizational structure to the Facebook Social Network, in order to make communication and decision-making processes possible. Therefore, they had to set up the communication platform and establish the protocols needed for each expected case. The social network served as a documentary repository, where images and videos were incorporated, and where third-party services were linked in order to publish documents and presentations. With all this, the student developed the skills necessary to carry out a collaborative design project in a virtual way.

3.2 Project management

The students had to make a project development plan [38], and a date for the unveiling ceremony of the sculpture was set right from the outset. For this reason, it was necessary to organize the different phases and subphases of the project development, as well as the milestones to be achieved by specific dates.

Hence, each subgroup established the tasks to be performed and the person responsible for each task based on this planning, in order to develop the products needed to accomplish the milestones within the set time. By so doing, students learned how to manage a collaborative project to be carried out in a limited amount of time.

3.3 Design process

The students acquired skills related to conceptual design working in a collaborative way. They made their own proposals, criticized the proposals of their teammates by trying to choose or improve the design, and they had to reach agreements with the rest of the subgroup members in order to decide on the final design. Once the final design had been defined, the students had to build a physical model to assess the technical feasibility of the proposal, and study the processes needed for its manufacture.

In order to assess the formal coherence of the sculpture, each subgroup developed a virtual 3D model of all the pieces that make up a column. Subsequently, the pieces were assembled virtually on a steel tube (Fig. 4). In doing so, they had to study the dimensions of each piece and its placement on the structure.

Finally, the different plans for each piece were developed from the 3D model. All dimensions were oversized according to the % of LC calculated for each type of ceramic clay—a calculation that was carried out in an earlier phase of the project.

With this, the students developed the ability to display, both in a virtual and a material way, a previously conceived volume. In addition, they had to come to an agreement with the whole group of students that are part of the project on the formal

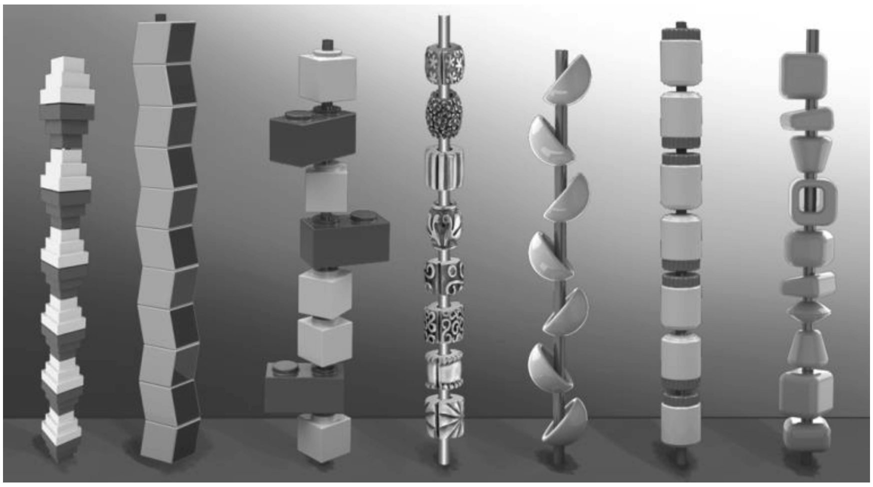

Fig. 4. 3D simulation of the 5 columns made with the SolidWorks software.

coherence of the whole sculptural assembly by making minor changes to the initial designs.

3.4 Manufacturing process

Before beginning the process of manufacturing the pieces, the students prepared the colour palette in a collaborative way. Ninety different colours had been achieved by combining all the available ceramic clays, the different glazes and ten colour formulations resulting from mixing several ceramic pigments. Accordingly, each subgroup had to produce some supports, weigh a few compositions and decorate a few test pieces. In consequence, a broad colour palette was achieved in little time for use by all the subgroups.

Concurrently, the %LC of each ceramic clay used was calculated in a collaborative way, in a similar process to that employed for the colour palette. In this case, the students chose to triple the number of tests and then find the average of the measurements. By so doing, the error of one subgroup could be offset by the others.

The manufacturing process needed for each piece was studied from the plans obtained from the 3D model, considering the singularities of the material, drying times and the inexperience of the students (Fig. 5). In many cases, they started with ceramic clay of a thickness that was oversized. Once the volume had been built, it was emptied of thicknesses in order to make construction simpler. The result responded to the design specifications.

Tooling had to be built for the construction of some parts. Specifically, two rolling mills, some taps for rounding corners of different diameters, or templates with the development of surfaces of revolution were built.

Finally, there was a collective firing plan. Each piece received two firings, a bisque firing at 960°C

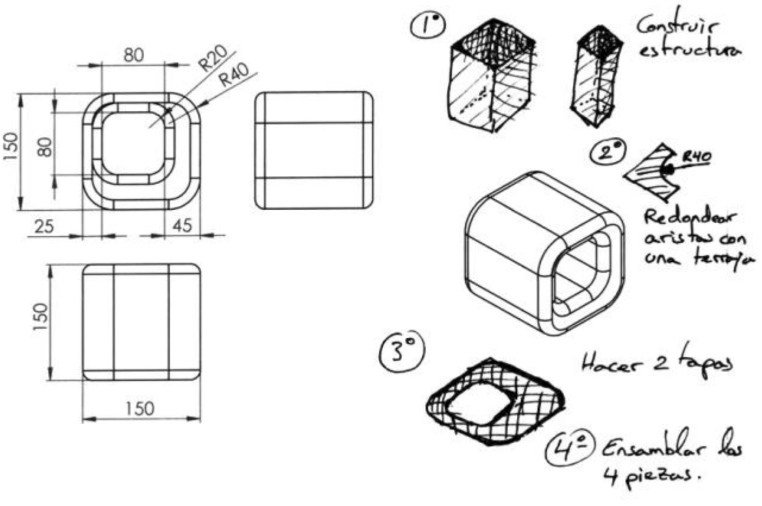

Fig. 5. Manufacturing plans with modelling considerations.

Fig. 6. Piece of glazed ceramic fired at 1260°C.

and a final firing at 1260°C once the piece had been glazed (Fig. 6). Only one of the two available kilns (Fig. 7) was able to reach such a high temperature, which meant that it was necessary to organize the firing appropriately. It should be noted that each firing lasted for 24 hours, including the cooling phase and that each firing allowed for a maximum of three pieces.

In the process of decorating the pieces, each subgroup chose the colours that best suited each column from the colour palette produced at the beginning of the project. Starting out from the reference of the test piece, it was necessary to repeat the composition in order to prepare the amount required to cover the piece. Once the pieces had been fired, the students went on to the distribution and assembly of the pieces on the steel piping structure by using chemical adhesive, in order to achieve the final columns.

At this stage, the students have acquired many skills related to the interpretation of manufacturing plans, construction techniques, firing processes, etc.

3.5 Documentation process

As in a real engineering project, all the design processes and their development were documented through reports. The purpose of doing this was to generate formal knowledge allowing a reduction in development time in future projects. The documentation included ranges from the previously consulted information to all the results and decisions taken during the design process, manufacturing of plans and the process of assembling the sculpture. In this way, the students discovered the importance and complexity of registering all the processes and decisions that led to the final product.

3.6 Installation

The installation of the sculpture was studied in this last step. Here, the decision regarding the location was made in response to not only aesthetic criteria, but also factors involving the safety or transit of people. Each student made contributions to the subgroup and this then made a selection that was submitted to the group. Subsequently, the chosen options were submitted to the directorate of the centre, which then made the final decision. Once the location had been determined, the different columns were distributed at the place chosen, following criteria of compositional harmony, reading order, etc. (Fig. 8). This stage allowed the students to acquire competences related to interventions in public spaces. Moreover, they had to submit properly documented technical proposals to an ''official'' agency for it to make the final decision.

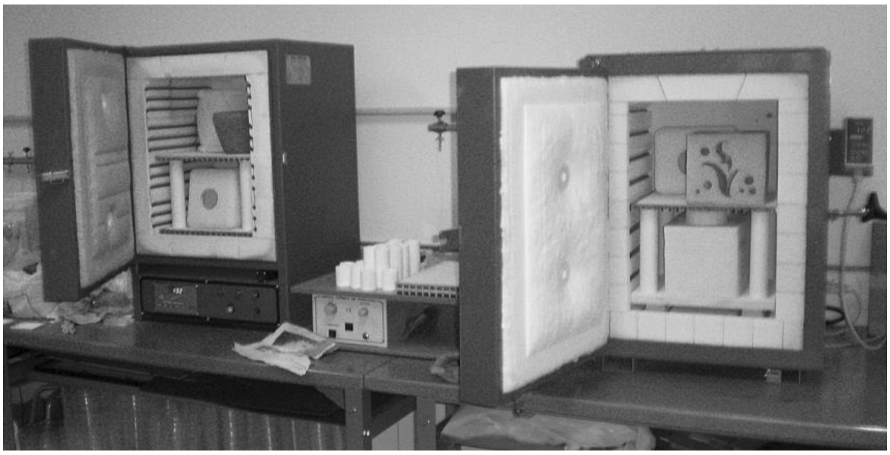

Fig. 7. Firing kiln.

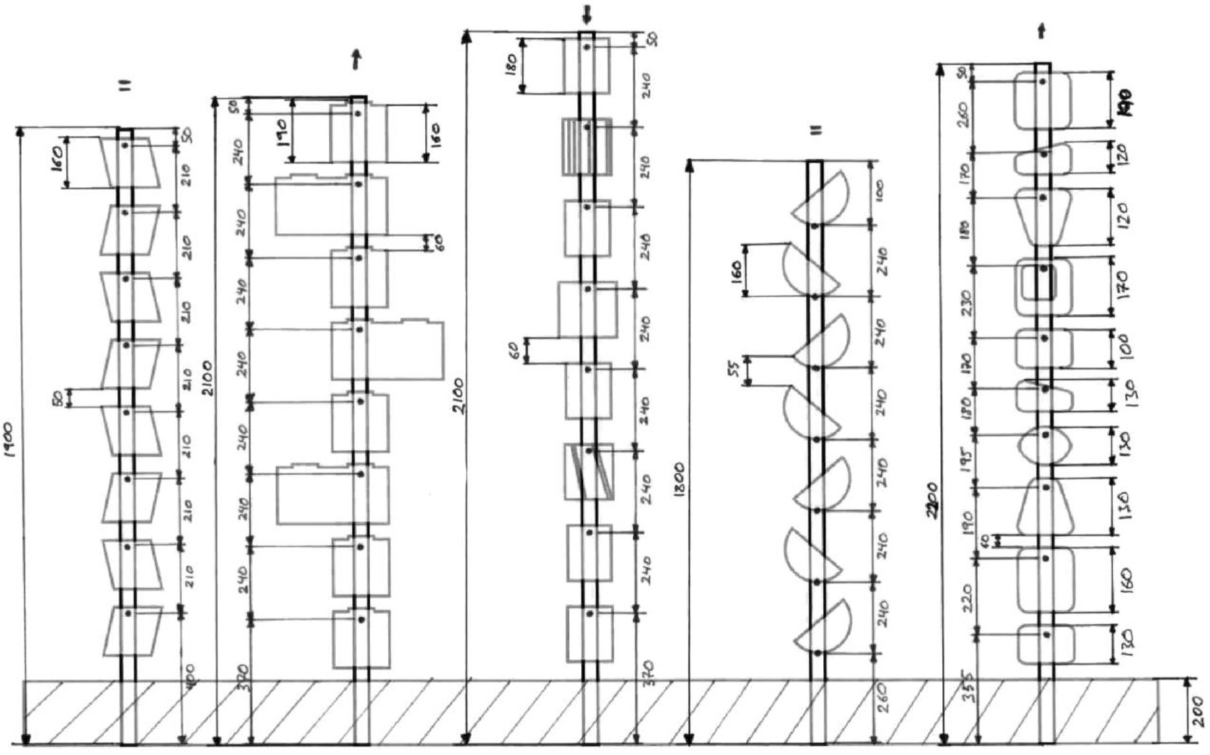

Fig. 8. Installation of the sculpture.

4. Results

As a result of the experiment, the students developed a collective sculpture that was installed permanently in the main entrance to the educational centre. The sculptural assembly (Fig. 9) consists of five columns made of glazed ceramics on a steel structure, occupying a space of about 6 m2. The height of each of them varies between 160 and 200 cm. In all, 41 parts of volumetric glazed ceramics were designed and developed, with a maximum dimension of 20–30 cm. The pieces were made with different chamotte clays, decorated with different commercial glazes for high temperatures, and pigmented according to the colour palette that was developed by the students. Natural oxides were

Fig. 9. Final sculptural assembly installed in the entrance to the educational centre.

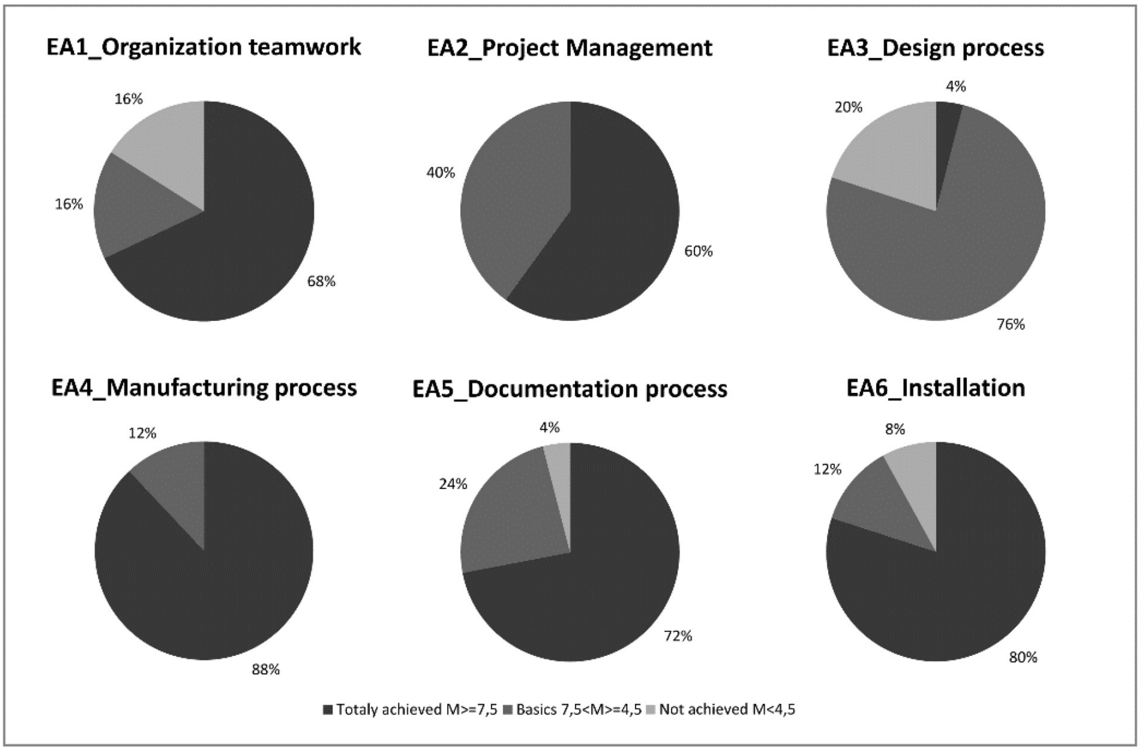

Fig. 10. Development of engineering abilities (percentage of students who have achieved each skill).

used, applied directly over the glaze, in order to improve the surface decorations by providing chromatic effects. Each piece underwent two firing processes. One initial bisque firing at 960°C was performed in order to ensure the consistency of each piece before its decoration, and an end firing at 1260°C was applied after the surface decoration had been carried out. The products obtained in this way were durable and resistant to the climatic conditions in the area. The assembly was made on a steel tubing structure consisting of five columns anchored in the ground through a small cylindrical concrete shoe.

According to Olds, Moskal & Miller [39], assessment methodologies can be divided into two primary types: describe studies or experimental studies. For the first type, they provide several techniques, such as surveys, interviews, focus groups, conversational analysis or observation. For the second type, experimental studies, they focus the assessment methodologies in the comparison of different approaches based on experimental designs with control groups.

The present study shows an assessment of specific competences—engineering abilities—related with the Design Engineering field, developed by a control group students in an experimental activity. For this purpose, quantifiable indicators have been fixed in order to evaluate the student's evolution in each of the developed aspects. The valuation of the corresponding group tasks, distributed and developed in a concurrent way by the different group members, have been considered equal for all members of each group. The valuation of the individual tasks within the group has been evaluated individually.

Figure 10 shows the percentage of students who have achieved totally each engineering ability—grade higher of 7,5 over 10-, those who have achieved a basic level of the ability—grade between 4,5 and 7,5-, and the percentage of students that has not acquired the ability—grade lower than 4,5-.

The average of the qualifications obtained by the members of each group has been calculated for each evaluated competence, as shown in Fig. 11. This allows assessing the achievements of the groups separately. Fig. 12 shows the dispersion of the qualifications obtained by all the students in each assessed competence.

When the experience ended, students were asked to fill a questionnaire to rate the operation of the project and the level of students' satisfaction within the proposed working system. The questionnaire consisted in a set of 20 questions that use the Likert scale of 5 intervals. The value of 1 corresponds to "strongly disagree" and the value of 5 to "completely agree". The asked questions were:

- Q1 The contents covered
- Q2 The difficulty of the contents
- Q3 The lectures

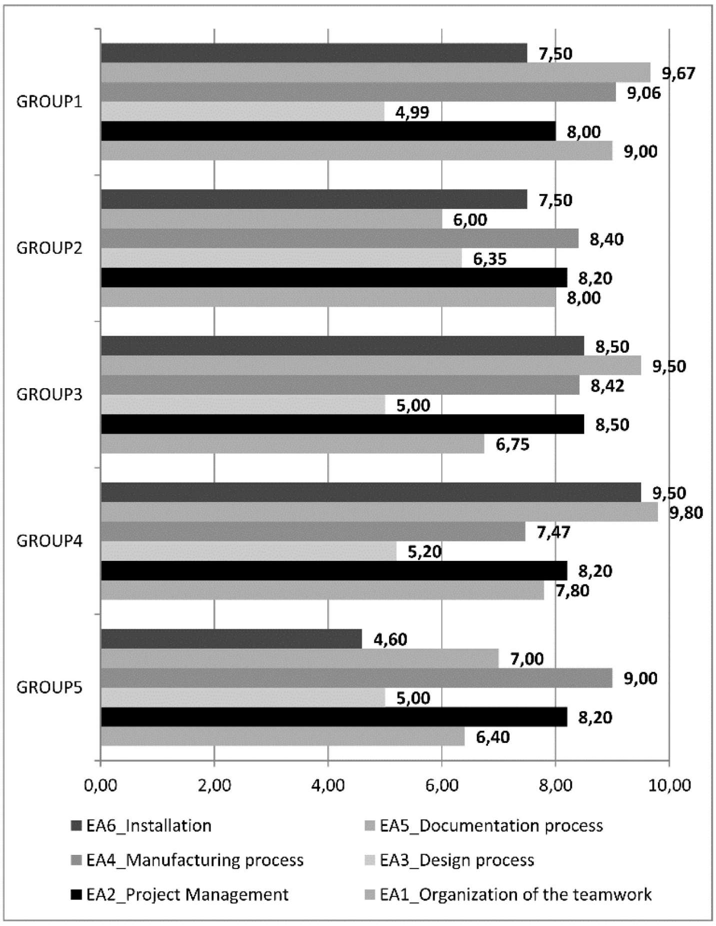

Fig. 11. Development of engineering abilities (average of each group).

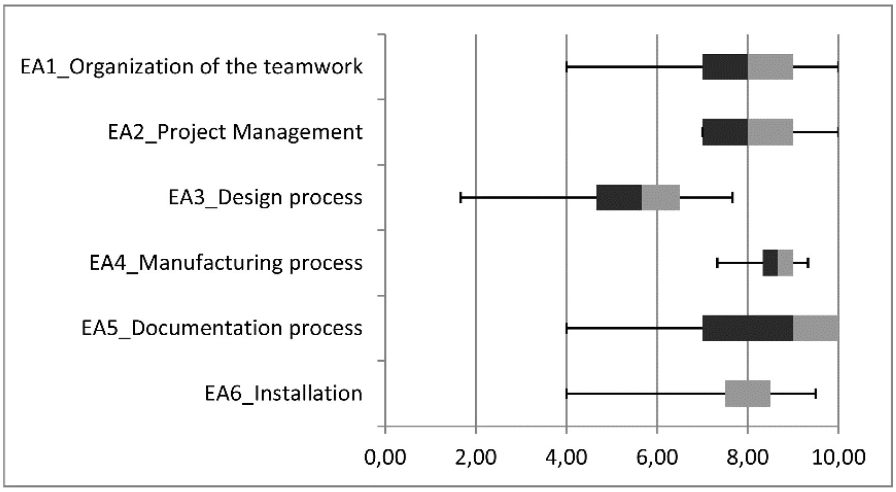

Fig. 12. Development of engineering abilities (spread of each ability).

- Q4 The presentations
- Q5 Classroom organization
- Q6 The techniques and procedures
- Q7 Teacher support
- Q8 The level of requirements
- Q9 The quality of the documents
- Q10 The quantity of documents
- Q11 The usefulness of the documentation
- Q12 The way of distributing the information
- Q13 The usefulness of Facebook in the project
- Q14 The difficulty of using Facebook
- Q15 The academic use of Facebook
- Q16 Will you use Facebook to coordinate a new project

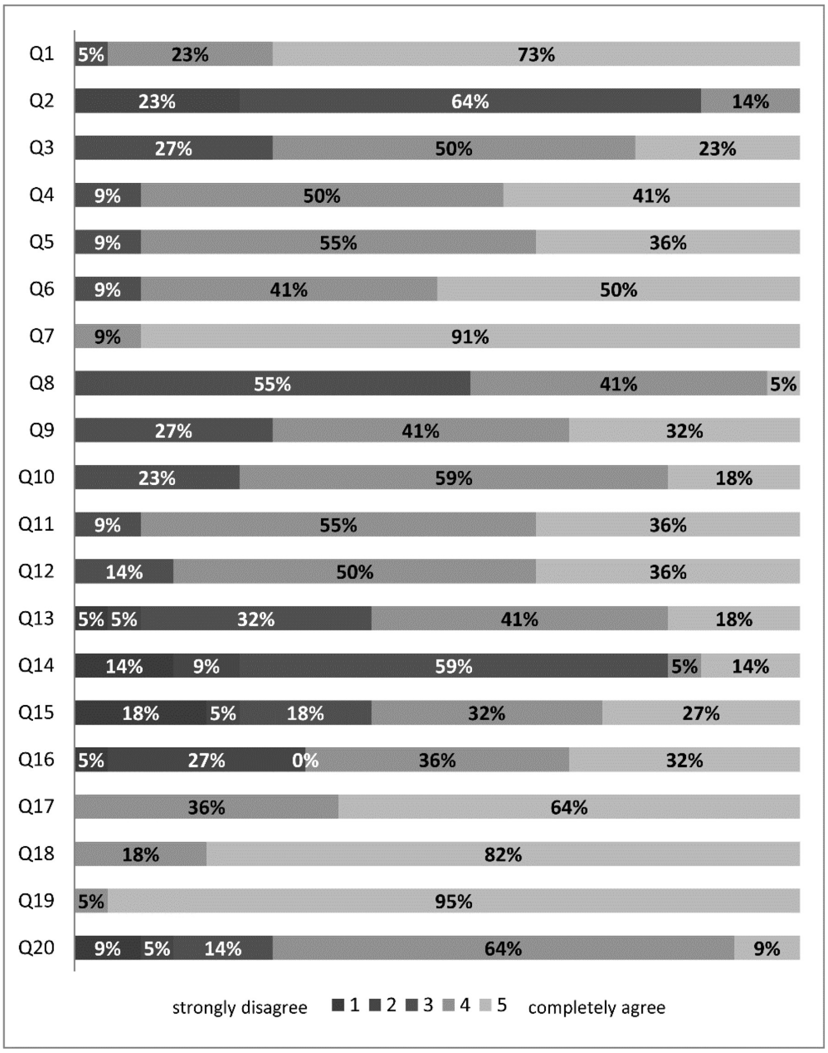

Fig. 13. Evaluation of the project by students.

- Q17 Motivation transmitted by the teacher
- Q18 The assistance provided during the project
- Q19 Teacher knowledge on the subject
- Q20 Evaluation criteria

Figure 13 shows the percentual values of the students' opinions for each of the raised questions.

5. Discussion

The present study allowed K-12 students to discover the work processes related to Design Engineering. In order to achieve this goal, a methodology based on informal learning was used, which allowed the students participating in the experiment to develop engineering skills in a "playful" way.

The students discovered mechanisms for teamwork organization based on the assignment of roles. A development plan was drawn up for the management of the project, given the available resources, in order to develop the products ordered within a limited time. In addition, the different phases of a design project were carried out, from the conceptual design of the proposal to the 3D modelling of the different parts, or even the development of the manufacturing plans of each piece. The students also developed a plan of manufacturing processes and built the different parts that led to the final product, which was installed on a permanent basis in the educational centre. Finally, they documented all the processes undertaken.

As has been seen in the results presented above, the students were able to make up for their shortcomings, both technical and creative, by generating the collective knowledge that is necessary for the resolution of the project at hand. The creative team, composed of 25 students, was able to develop a single product with a shared authorship. The numerous consensuses achieved through the virtual discussions carried out through the Facebook social network made it possible for each member of the creative team to participate actively in the final solution, contributing some uniqueness to each task in the work process.

As shown in Fig. 10, all the evaluated abilities have achieved a high percentage of "totally achieved". The exception was EA3 "Design process", which presented more moderate results. Even so, the level of knowledge achieved in this ability has been adequate. Moreover, results show a low percentage of students with a non-achieved competence. Fig. 11 points that there is no homogenous result regarding to the acquired abilities within each sub-group. The different sub-groups present their best results in some or others abilities. None of them present a "totally achieved" valuation in all the evaluated abilities. Fig. 12 shows the dispersion in the qualification of all the students according to the evaluated abilities. It can be appreciated that EA4 "Manufacturing process" provides with the most homogenous results. EA1, EA3 and EA5 present the higher dispersion. Among them, EA5 has the higher dispersion in the "box zone", this is, between the percentiles 25 and 75. As intuit in Fig. 10, Fig. 12 reinforces the fact that EA3 has been the less assimilated ability by the students. Despite this assessment, the dispersion in the central zone, where the 50% of the population is present, is not very high. Moreover, it is remarkable that the median is quite high in all of them.

Regarding to students' satisfaction, Fig. 13 reveals a success in the purpose of motivate the students, since all questions present positive results in general lines. Questions Q7, Q17, Q18 and Q19 are remarkable, since they refer the role of the teacher during the project. So, students have valuated positively the implication of the teacher in the activity. On the other hand, the questions Q2, Q8, and Q14, related to the difficulty in a specific part of the project, present the lowest marks. Focusing in the use of social networks, the 68% of the students will use again the Facebook for coordinating a new project. Moreover, the 86% of them liked the way of distributing the document through that social network and using, if necessary, third party tools as Scribd or YouTube. These facts demonstrate that the students perceive the social network Facebook useful for facilitating the communication process between a large group of creatives.

6. Conclusions

Thanks to this experiment, the students discovered their chances of working within the field of engineering. Hence, their interest in initiating studies in Engineering once they get beyond the pre-K-12 stage was promoted. It can therefore be said that the target set out at the beginning of the study was achieved.

Nonetheless, it is considered interesting to track the students that have participated in the experiment in order to ensure the effectiveness of motivating them to choose engineering studies. In this way, it will be possible to observe directly the influence of the case the kind of university studies selected by each student.

Moreover, the authors considered it interesting to undertake new similar experiments that focus on the design and development process of products composed of some kind of mechanical or electrical system. This could encourage students to access other specialties of the field of engineering.

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