TEACHING AND LEARNING INNOVATION IMPACTS

Analysis of undergraduate students' reflections when working on non-formal science activities

Student reflections in non-formal science activities

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1. **ABSTRACT:** Dues activitats no formals de ciència van ser escollides com a plataforma per als estudiants universitaris per millorar les seves competències comunicatives. Els estudiants van respondre a una llista de preguntes per a la reflexió. Quatre unitats completes van ser inferides després d'analitzar les respostes dels estudiants i es van classificar en dues categories: metodològica (descripció, argumentació i contribució) i reflexiva(comprensió, reflexió i reflexió crítica).

2. **ABSTRACT:** Two non-formal science activities were chosen as platforms for undergraduate students to improve their competencies, especially in communicating science. Students answered a list of reflective questions. Four complete units were chosen with which to analyze the students' responses and which were classified into methodological (description, argumentation and contribution) and reflective (understanding, reflection and critical reflection).

3. **KEYWORDS:** Aprenentatge reflexiu, competències de comunicació, activitat no-formal.

   KEYWORDS: Reflective learning, communication skills, non-formal activity.

4. DEVELOPMENT:

Introduction

Dewey (1933) established the pragmatic notion of reflection by distinguishing reflective action from routine action. Reflection has, from his point of view, the purpose of addressing consciousness and thoughtfulness about one's actions. As Dewey (1933) pointed out, the process of reflection consists of a linear model of successive phases, moving from an initial interpretation of experiences through to defining hypotheses and testing or experimenting with them. Later on, cyclical reflection models for educational settings were suggested (Kolb, 1984; Korthagen, 1985) postulating that reflection encourages learners to take an active role in finding solutions to complex problems. Kolb (1984) and Kolb and Kolb (2005) suggest that learning is the creation of knowledge through the transformation of experience. Experience may well be the basis of learning, but learning cannot take place without reflection and, while reflection is essential to the process, it must be linked to action. Along these lines, Schön (1983) described reflective practice as a dialogue between thinking and doing via which the learner becomes more skilled. This involves integrating theory and practice, and thought and action (Felder, 1988; Osterman and Kottkamp, 1993; Scott, 2010). Learners should go through the cycle several times, so it may best be thought of as a spiral of cycles (Healey and Jenkins, 2000).

Although the use of reflective education-focused activities is a significant factor that contributes to optimizing the impact of teaching, the use of reflective activities has yet to be fully explored in Science, Technology Engineering and Math (STEM) education and their application should be reinforced (Felder, 1988; Mackenna et al., 2009). As pointed out by Songer and Ruiz-Primo (2012), more attention should be paid to STEM education practices based on instructional effectiveness and better assessment. Translating knowledge activities into a useful form for teaching is a way of emphasizing greater pedagogical knowledge (Alonzo et al., 2012). Abdulwaked and Nagy (2009) pointed out that the impact of laboratory education on students' learning is still to be recognized and a rethinking of the role of the laboratory in Engineering and Science education should be considered. These authors report that Engineering and Science students should experience constructivist pedagogy to gain autonomy in the learning process and, in return, this kind of education could serve as a motivating factor toward an engineering or scientific career.

Writing, reading, listening, talking and reacting can be used as tools not only to stimulate reflection for continued personal development as teachers (Broekman and Scott, 1999), but also as citizens, when facing important decisions in problematic environments under extreme pressure. There is also a belief that writing leads to improved awareness. Furthermore, developing writing as one element of the reflective process is a skill that can be used continuously to aid reflection (Broekman and Scott, 1999). Broekman and Scott (1999) also stated that the use of the term `reflection' in the professional context implies a base of change and refinement in practice. They also point out that writing is a way of moving thoughts from the head to paper, thus enabling future discussion and development of the ideas. Writing also forces everyone to participate, contrary to what might happen in collaborative interviews which might only represent the opinion of only a few.

Non-formal education is the learning that occurs in a formal learning environment but that is not formally recognized within a curriculum or syllabus framework (Niculae et al., 2011). Most researchers agree that the declining interest in Science studies noted in young people is largely due to the way Science is being taught in schools (Rocard, 2008). The `Resarchers' Night' and the `Science for All' fair are social events open to people interested in Science and offer platforms for explaining scientific aspects in an attractive and engaging way. Learning is then considered to take place in a community-centered environment. Both events use a method based on transmitting Science through `hands on' experiments. The aim of these events is to reduce the decline in learning basic Science among youth.

In this study, `Researchers' Night' and the `Science for All' fair were used as a platform for undergraduate students to improve their competencies. Eight undergraduate students (under the supervision of a teacher) volunteered to communicate scientific experiments to an audience mainly made up of children. The students had discussed the basis of each experiment with the teacher before the event and then, after the event, the teacher asked them to answer a questionnaire to promote self-reflection as a way to improving awareness in how to communicate Science to a broad audience in a non-formal scenario.

Method

The experiment was carried out with a regular group of eight volunteer undergraduate students from different faculties (two from the Science Faculty and five from the Polytechnic School) in the academic year 2015-2016. As the aim was for the undergraduate students to improve their competencies in communicating science, each student was asked to answer eight questions individually (Table 1) one day after demonstrating and explaining their experiment to an audience predominantly made up of children. Questions focused on what was required to be able to effectively communicate science to a general audience. The answers were then analyzed by the authors of this manuscript by combining structural and descriptive coding processes (Saldaña, 2013). Based on the degree of depth of reflection the students reached, codification was considered to depend on two different and complementary categorization processes, i.e. methodological and reflective. Both categorizations were consistent with the results of Chamoso and Cáceres (2009) and Kember et al. (2008) when assessing students' learning. The methodological categorization (Table 2) was based on the awareness of the learning process while developing the action (Description, Argumentation and Contribution), whereas the reflective categorization (Table 3) was established based on the degree of

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personal reflection (Understanding, Reflection and Critical Reflection) according to Kember et al (2008).

Once the authors of this manuscript had independently revised the students' work, four key indicators were chosen to assess the level of reflection and methodology of the students involved. These indicators were extracted from the students' answers to the questions raised and were considered to be complete units of information. A complete unit of information is an idea or thought about a particular topic or event (Chamoso and Cáceres, 2009). The indicators chosen were:

1. I adapt my oral language to the needs of the audience.

2. My action requires previous scientific knowledge.

3. In developing the action, I have learnt something about science and/or methodology or both.

4. I am watchful and aware of the audience and I try to get a feedback to improve in the activity.

Among the methodological categories, Description was considered to be when the student understood the process of communicating science as a repetitive action focusing on transmitting science on a formal level. The student describes communication as a narrative process and a mere transmission of knowledge. In other words, it was not adapted to the needs of the audience at all. The student summarizes what they have explained during the action in which they were involved. Argumentation implied that the students transmitted the action actively, including partial feedback, and paid special attention to the audience and their reaction. The learning process is seen as summative, as a result of seeking examples, applications and conclusions of the scientific experiences. Contribution was considered to be when the student transmitted science in an active process, that included inquiring, obtaining full feedback and making their own contributions as a measure of being involved in the development and improvement of the activity. The feedback was adapted to the audience and the student was fully aware of and attentive to the different levels of the scientific understanding or knowledge of the audience.

Among the reflective categories, Understanding does not imply reflection. Science is understood but expressed in a formal way without being related to personal experiences or real-life applications (Kember et al. 2008). The basis of the scientific experiments is expressed as a mere repetition of that given by the teacher in the session before the activity's initiation. In the absence of reflection, the students demonstrates a low-level of involvement and barely expresses the relationship between the theory of the experiments and the practical situation. The students express, correctly or partially correctly, their previous knowledge of the theory. The experience is compared to an exercise that could be read in a book, therefore student implication is totally absent. In contrast, Reflection includes relating or connecting the theory to their personal experiences. The student

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clearly defines the framework in which theory is delimited in the practical action. Here, the personal experience in transmitting science in non-formal scenarios is seeing as a model to test personal competences. Despite having been previously taught by the teachers, the students involved in the action expressed personal insights that went beyond practice. And finally, Critical Reflection is considered to be when the student undergoes a transformation. In other words, the student assimilates the action of transmitting science and points out a changing perspective of the action. The student adopts a new conceptual model in which, when transmitting science, they express and/or demonstrate modes of creativity and personal engagement. The student uses feedback as a way to increase personal comprehension of the learning process.

Based on the dimensions used in the research for assessing reflection, the method chosen by the student in the reflection process of each of the four previous indicators was considered as being able to be graded according to the methodological categorizations (Table 2). The four above-mentioned indicators were also categorized depending on the degree of reflection when the three different levels of reflection were taken into account (Table 3). Examples of how each student's answers to the questions were categorized are given in Table 4 (Annex section). An explanation with the interpretation made throughout the categorization process has also been added to the table.

Results

There was a high level of participation in the activity; seven out of the eight students that attended the non-formal science events answered the questions. They were motivated during the event and also with the ensuing reflection activity. Six of the students participated in both activities and three highlighted the differences in the methods they followed between the two events.

From the methodological categorization, students mainly described the activity carried out and contributed to the activity by adding more material which was valuable for the development of the non-formative event (Figure 1). Only a small percentage (25%) managed to give an argument of their reflections. The level of description was greater for indicators 1, 2 and 3 I adapt my oral language to the needs of the audience, My action requires previous scientific knowledge, and In developing the action, I have learnt something about science and/or methodology or both) while for indicator 4 (I am watchful and aware of the audience and I try to get a feedback to improve in the activity) they undertook a more argumentative methodology (Table 5). Only one neither knew nor had any indication about what the audience thought about their development during the activity. For indicator 3 (In developing the action, I have learnt something about science and/or methodology or both), when they explain the evolution in their development during the activity, none of the students attempted to do this with an argumentative methodology, rather they mainly described their thoughts. Several students contributed to

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the activity by pointing out the method they used to adapt the language to the audience and its needs, the way they obtained feedback from the audience or to how they managed to acquire the information required from the audience in order to be able to introduce the information needed to develop the experiment.

When the categorization was made in terms of the level of reflection, the majority of the students' reflections about the activity were on the level of understanding (Figure 2). Only indicator 2 (My action requires previous scientific knowledge), which was related to the basics needed to perform the activity, was essentially answered using reflection (Table 5). The majority of the answers to this indicator reflected scientific knowledge with only one student response about the methodology used during the activity. The student that did so was one of those who participated in both activities. Furthermore, 32% pointed out that they had searched for new methods, not indicated by their teachers, to develop the non-formative event, indicating an important degree of creativity and critical reflection (Figure 2).

Discussion

Results from the categorization of the indicators demonstrate that students prefer description methodology to argumentation and contribution. A mere 25% of them undertook argumentation narratives when reflecting about their implication in the activities. After the description, they made contributions about how they managed the activity and evidenced a critical point of view about how they could improve (related to indicators 1, 2 and 3, i.e. I adapt my oral language to the needs of the audience, My action requires previous scientific knowledge and In developing the action, I have learnt something about science and/or methodology or both, respectively). Argumentation was the preferred methodology when they explained their thoughts about the reaction of the audience (related to indicator 4: I am watchful and aware of the audience and I try to get a feedback to improve in the activity). In this situation, they stated their reasons for discerning how their audience had reacted to their work. Only one of them did not discern any indication from the audience. The different percentage of distribution in the methodologies adopted for the different indicators might be because it was the students' written reports that were being dealt with, which may have limited their ability to convey the breadth of their thoughts. Most of the students are not used to writing about the way they perform an activity and/or about reflecting on their activity, rather they are used to obtaining results and coming to grips with concepts, especially scientific ones.

Results from the reflective categorization of the indicators demonstrate that students produced low levels of reflection for indicators 3 (In developing the action, I have learnt something about science and/or methodology or both) and 4 (I am watchful and aware of the audience and I try to get a feedback to improve in the activity). However, they did prefer to use reflection for indicator 2 (My action requires previous scientific knowledge).

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In this latter situation, students refer to their background in science, rather than the non-formative science event activity or the self-reflection process undertaken. For indicator 4 (I am watchful and aware of the audience and I try to get a feedback to improve in the activity), none of them showed reflection, the majority reached the level of understanding, but only two of them demonstrated a critical reflection level. Chamoso and Cáceres (2009) made a similar categorization based on a written activity. They pointed out the importance of using other tools such as individual or collaborative interviews to increase the level of reflection. However, an interview with the same questionnaire could have differed greatly, mainly due to teacher guidance or the fact that the opinion of the majority might have ruled. Poldner et al. (2014) made a quantitative evaluation of the reflective level of student-teachers during two consecutive semesters and they found that the modes of their reflective essays were mainly descriptive and evaluative. They stated that students need to be encouraged to reach the highest levels of reflection that they named as justification, dialogue and transformative learning. They also found an improvement in the reflective level over semesters, probably due to the feedback activity carried out during the semesters. This fact indicates that students' reflective writing can be stimulated by teachers' formative assessments, whereby teachers provide guidelines to students about the quality and level of their reflection and suggest ways of improving their reflections. Bain et al. (2002) also pointed out that feedback on students' reflective writing is the most effective strategy in promoting a high level of reflection Therefore, including a feedback task in future activities would enhance the level of student reflection.

Some students do not show a great level of discussion and reflection. This fact might be due to not being used to engaging in reflective activities at university, where contents still has the greatest weight in the curricular development of a student. However, communicating science in non-formal scenarios produced significant differences between students in their abilities to continually make judgments and decisions in dynamic learning environments or in changing situations under pressure. In contrast, students were motivated by the activity; as has also been found in a reflective assessment in medical education (Veno et al., 2016). In order to assess whether undergraduate students have the level of reflection necessary, choosing a group of students randomly would be required. Then, we would be able to compare the level of reflection between those students and the level of reflection obtained with the group of volunteers from this present study. One would expect a greater reflection level from the volunteers, than that of the randomly selected group.

Conclusions

Two non-formal formative events were selected to encourage students to self-evaluate and reflect on their actions while getting involved with the communication of and explaining scientific experiments. Self-evaluation was carried through reflective narratives where students could summarize, discuss, argue and justify the action through a set of

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reflective questions. The study provided a tool to assess students' reflective thinking with regards to the activity developed. Two categorizations were considered at coding the implication in communicating science activities, a methodology categorization and a reflective categorization. Description and contribution were the methodological categories for the majority of the indicators, albeit with the exception of the degree of feedback during the action, which was written in an argumentative form. Reflection was mainly used to describe the necessity of requiring previous knowledge in sciences in order to communicate scientific experiments and manifested low levels of reflection for expressing the level of feedback during the activities and the knowledge gained while carrying out the activities. All in all, this manuscript describes a reflective strategy that may be an instrument for detecting the capacities of university students to communicate science to a broad audience in a non-formal scenario and is seen as an opportunity to enhance personal communicative skills as well as to enhance self-development and personal improvement.

4.1. GRAPHIC OR TABLE 1

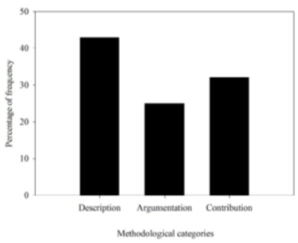

Figure 1. Percentage of categorization for the different methods considered.

4.2. GRAPHIC OR TABLE 2

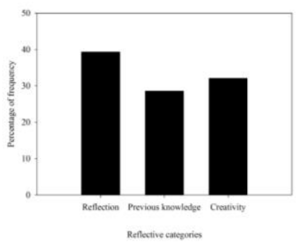

Figure 2. Percentage of categorization for the different levels of reflection achieved.

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4.3. GRAPHIC OR TABLE 3

Table 1. List of questions the undergraduate students were asked.

1.	What do I need for the activity?
2.	Do I know the basic knowledge and methodology needed to carry on the activity?
3.	What do I need to search for to develop the activity?
4.	How can I organize myself to develop the activity?
5.	Can I identify the difficulties in developing the activity before doing it?
6.	Can I search for ways to improve? How do I do this?
7.	What did I learn with the activity?
8.	What do I think the audience feels? Did I think they understood my explanation? What do I think about my way of explaining? Why?

4.4. GRAPHIC OR TABLE 4

Table 2. Methodological categories and a short description of each of them. The category names and descriptions are as follows:

Description	Argumentation	Contribution
When the student participates in the process taking an external point of view	When the student participates actively in the process with an active interest in understanding the process and the implication of the activity	When the student, besides participating, becomes involved in the process by taking his/her own decisions

Table 3. Reflective categories and a short description of each of them. The category names are as follows:

Understanding	Reflection	Critical reflection
When the student explains the activity carried out without relating it to previous knowledge	When the student relates the activity to previous knowledge, reflects but does not create or search for any other model to improve with	When the student evaluates and reflects on their activity and tries to find ways of critically improving without the help of the teacher

4.5. GRAPHIC OR TABLE 5

Table 4. Examples of the students' reflections and the categorization made. An explanation of the interpretation in the categorization process is included in the final column.

Description	I try to adapt the explanation and language to the age of the audience and when I feel that someone does not understand I find other ways to explain the concept.	The student describes the process followed throughout the event.
	The audience demonstrates interest in the experiments and when they do not understand something they ask questions.	The student describes their observations about what the audience does at the end of the event.
	I need to prepare the explanations and know how the experiments work.	The student describes the process before the event.
Argumentation	I think the audience understood the basics. I am happy with the results	The student gives evidence of the success of their activity
	The audience liked my explanation. I know because they told me several times.	The student gives evidence of their performance. They justify their interpretation.
Contribution	When talking to children it helps to explain the experiment as if it was a game.	The student thinks about the process undertaken during the activity and finds an evolution and reflects about the strategy followed.
	I was a volunteer to prepare explanatory material (drawings and schemes) to be used as a tool for the explanation.	
Understanding	I need to have the contents well prepared to reduce the risk when I am in front of the audience.	The student thinks about the contents and not about any methodology.
	I previously adapted the language to different audiences. Already available schemes and drawings were useful for the explanation.	The student prepares the method before the activity.
Reflection	I have to know basic concepts of physics, optics....	The student specifies the contents required.
	I need to know how to talk in front of an audience and I need to have enthusiasm to participate.	The student specifies the method and their attitude in front of the audience.
Critical reflection	You need to choose the experiment you feel more comfortable with and not the easiest one.	The student gives their own clues/reasons to choosing the activity to undertake.

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4.6. GRAPHIC OR TABLE 6

Table 5. Results of both methodological and reflective categorizations for each of the indicators considered.

Indicator	Methodological categorization	Description	Argumentation	Contribution
1		3	2	2
2		3	1	3
3		4	0	3
4		2	4	1
Indicator	**Reflective categorization**	**Understanding**	**Reflection**	**Critical reflection**
1		2	2	3
2		0	5	2
3		4	1	2
4		5	0	2

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