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# Critical Thinking, Real Life Problems and Feedback in the Sciences Classroom

Carolina CARVALHO[1], Edite FÍUZA[2], Joseph CONBOY[3], Jesuína FONSECA[3], João SANTOS[4], Ana Paula GAMA[5], Maria Helena SALEMA[3]

[1]Assist. Prof. Dr., Education Institute of the University of Lisbon, Lisboa-Portugal
[2]Assist. Prof. Dr., University Lusófona of Humanities and Technologie, Lisboa-Portugal
[3]Research. Colab. Dr., Education Institute of the University of Lisbon, Lisboa-Portugal
[4]Research Assist., Education Institute of the University of Lisbon, Lisboa-Portugal
[5]Assist Prof. Dr., Instituto Superior Dom Afonso III, Loulé-Portugal

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## ABSTRACT

This descriptive and interpretative study was aimed at better understanding how to foment effective feedback in the sciences classroom by implementing an activity based in a real-life problem that was intended to promote critical thinking. Eleven secondary and pre-secondary public school teachers participated in a workshop in the Greater Lisbon area (part of a year-long continuing education project). In one three-hour session, they performed an activity intended to promote critical thinking, based on a real-life problem, and received feedback from a workshop facilitator. Participants responded to two questionnaires concerning the nature of the activity performed and the feedback perceived. Interpretative analysis of responses indicates that the activity performed was perceived as a real-life problem and the feedback was perceived as effective. The outcomes and conclusions contribute to a possible understanding of how such an activity can facilitate effective feedback in the sciences classroom.

**Keywords:** Feedback; Teacher Education; Critical Thinking; Real Life Problems.

## INTRODUCTION

It is widely recognized that feedback is among the most powerful influences on how people learn. According to the scientific literature, frequent and continuous feedback about the level of understanding of the topics under discussion produces gains in conceptual understanding, attitudes and performance (Brookhart, 2008; Hattie, 2012).

The nature of the feedback that students receive from teachers may be influenced by the nature of the proposed classroom activities. Based on the literature, the implementation of activities intended to promote critical thinking is a strategy that facilitates teachers' communication of effective feedback to their science students (Bóo, 1999; Klassem, 2006). But how does this happen? . We seek to understand in what ways teachers' use of effective

Corresponding author e-mail: cfcarvalho@ie.ul.pt

feedback can be facilitated in the sciences classroom by implementing an activity intended to promote critical thinking, embedded in a familiar, every-day life context. Two types of studies guided our literature review: (a) studies focused on defining effective feedback; (b) studies centered on promoting critical thinking and how this intersects with the process of problem solving.

**Framework for Effective Feedback**

The term *feedback* is defined by Wiggins (2012) as 'information about what we are doing in our efforts to reach a goal'. Feedback may be given either by observing the effects of our own actions, or it may be provided deliberately and explicitly by other agents. The information received should not be in the form of advice or judgment, but instead, it should be directly related to the effects of our actions. According to Wiggins (2012), feedback is frequently misunderstood. As teachers and parents, we often give advice without confirming that the learner has understood prior feedback. Without prior descriptive feedback, recommendations such as 'You need more examples in your report' may be useless. Faced with such advice, students may become increasingly dependent and insecure about their ability to learn, which may have an impact on their achievement (Wiliam, 2009).

Several authors report that teachers rarely tell students what they need to improve, that is, how to get from their starting point to the intended goals (Hattie, 2009; Valente, Conboy & Carvalho, 2009). Students are frequently faced with classroom evaluation and grades that are of little use for what they are learning. In fact, teachers frequently use comments such as 'Good job!' or 'This report is weak' that classify, praise or criticize what was done. There is little or no genuine feedback here, no useful information that will help students 'to assess their current achievement and to indicate what the next steps in their learning trajectory should be' (Black, Harrison, Lee, Marshall & Wiliam, 2010, p. 42). Instead, students are only provided information about their grades and a vague notion of the good or bad results of their effort.

Brookhart (2008), Hattie (2012) and Wiggins (2012) all present theoretical rationales that characterize the essentials of effective feedback. We can synthesize and summarize these essential points by indicating that effective feedback is (a) timely; (b) likely to be used; (c) tangible and transparent; (d) goal-referenced and (e) consistent. Each of these five dimensions is described below.

*Timely* feedback means that feedback is received shortly after, or while, the task is being performed. It does not mean that feedback should always be received immediately. That will depend on the task that is in progress. In any case, timely feedback, that which is presented just after, or still during the task, appears to be quite effective.

By *Likely to be used* we mean that the feedback provides information that is actionable by the learners, that is, they can act based on that information. It can be given informally during observations of learners doing their work.

*Tangible and transparent* feedback means that learners should perceive concrete results from their efforts toward the goal they pursue, instead of just hearing talk about the goal. Feedback should be given about topics clearly relevant to the activity encouraging learners both to make connections among their ideas and to carry on the activity without depending on the teacher.

*Goal-referenced* feedback implies comparing the work in progress with the pre-established learning goals. Task objectives must be stated clearly. Whenever necessary, they should be restated as a reminder, and alternative strategies can be suggested that will help students to figure out how to achieve those goals.

*Consistent* feedback provides learners with stable and trustworthy descriptions of what they did right, of what could be done to improve and about the gap between the two. Such

information, if received by students in a consistent manner over time, helps them to adjust their performance adequately.

These essentials can be used as a framework to describe in what ways classroom discussions, activities and tasks can promote the use of effective feedback. In fact, and according to Hattie and Timperley (2007), feedback about the quality of the work and feedback about the strategies used to do the work are more effective than feedback about students' self-regulation or about the student as a person. As such, it is important to clarify how the use of effective feedback can be facilitated by the nature and type of the classroom activities.

## Conceptualization of Critical Thinking

*Critical thinking* is related to a common core of skills concerning problem solving, decision making, inference, divergent thinking, evaluative thinking, reasoning and transfer. These skills are often referred to as *higher-order cognitive skills* (Leou, Abder, Riordan & Zoller, 2006) or *critical thinking skills*. Among the several definitions that have been proposed since Dewey (1910), Ennis (1987) defines critical thinking as 'a way of reflective thinking focused on deciding what to believe and what to do' (p.10). Ennis classifies a core of critical thinking skills in five basic areas: (a) elementary clarification, (b) basic support, (c) inference, (d) advanced clarification, and (e) strategies and tactics.

The first principle of *elementary clarification* involves focusing a question. In fact, a focus is crucial to know what is relevant. It includes identifying a problem, hypothesis or thesis in the form of a question. *Basic support* includes the ability to judge the credibility of a source. These may be statements made by others, or previous observations. *Inference* is categorized according to interdependent skills such as deduction and induction. The key aspects of *advanced clarification* are the definition of terms and identification of assumptions. The area of *strategies and tactics* involves two skills: 'deciding on an action', which includes steps inherent to the process of problem solving, and 'interacting with others' in discussions, presentations, debates and written text.

## Promoting Critical Thinking through Real-life Problems

As pointed out by Ennis (1987), the critical thinking area of strategies and tactics includes essential skills needed to solve problems. As such, considerations dealing with the promotion of critical thinking often involve the development of skills inherent to problem solving.

The NGSS Lead States (2013) presents the promotion of critical thinking and problem solving as indispensable conditions for effective learning in science. These are not only ways to prepare students for subsequent levels of education, but also for future professional careers. According to this document, from the first grade students should be expected to demonstrate '(…) proficiency in planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, and obtaining, evaluating, and communicating information' (NGSS Lead States, 2013, p.3).

As a strategy to promote critical thinking in the sciences classroom, several authors recommend the use of activities based on real-life problems as opposed to the routine exercises usually worked (McIntosh, 1995; Pine, et al., 2006; Pizzini, Abel & Shepardson, 1988; Swartz, Fischer & Parks, 1998). Wlodkowvski (2008) considers the use of real life problems as a means for people to learn critical thinking, collaboration, and the essential concepts and professional skills of a particular discipline. In addition, it is often argued that science students frequently have difficulties when developing problem solving processes to face real-life problems because the routine exercises solved in the sciences classroom are

typically based on domain-specific knowledge and require unique solutions (Lyons, 2006). Implementing learning activities based in real-life problems is viewed as a potential strategy to bridge the gap between the classroom and the real world (Weber, 2014).

By *real-life problems* we mean activities embedded in personal, community, social or global contexts. Neither the objectives nor the methods to solve these problems are wholly defined, and several plausible solutions may be acceptable. On the other hand, *routine exercises* are activities characterized by definite goals, with sufficient and explicit data provided to reach the solution. These problems imply familiar methods of resolution, involving a unique 'correct' solution. They require a mere application of algorithms in order to solve the task (Wood, 2006).

Real-life problems, by virtue of their multidisciplinary and uncertain nature, enhance students' critical thinking; they help students see the usefulness of learning and provide them opportunities for reviewing and choosing among various options (Newman, Griffin & Cole, 1999; Wood, 2006). In this way, real-life problems stand in opposition to routine exercises that yield correct textbook answers for the teacher to evaluate.

As the effects of feedback depend on the nature of the feedback, we seek to understand how teachers' communication of effective feedback can be facilitated by means of a science classroom strategy based on a real-life problem, intended to stimulate students' critical thinking.

## METHODOLOGY

### a) Context of the study

The present study was developed in the context of one of the sessions of a teacher education workshop- 'Feedback in the classroom: Dynamics and consequences for students' academic trajectories.' This workshop was structured in eight sessions of three-hours each, distributed one per month. The workshop objectives were for the participants: (a) to understand the concepts of student identity, school engagement, academic trajectories, and feedback; (b) to be able to identify good feedback practices in the education community; (c) to learn how to develop and implement constructive feedback strategies that would promote their students' learning and give meaning to this learning, and; (d) to analyze the feedback strategies they implement in their classes in order to reflect upon, and assess, their teaching practices. The teachers volunteered to participate and their school administrators provided space and equipment as well as assuring teacher availability for the workshop.

Pairs of workshop facilitators guided each session in a team-teaching approach. One of the team was responsible for a particular session and the other assured the continuity and articulation with former sessions. Also, after each session, participants were given assignments involving classroom application of, and reflection about, workshop topics.

During the first session, the facilitators sought to understand the perceptions of the participants on the concepts of assessment, feedback and engagement. Participants then confronted their perceptions with the existing literature, and framed them in the context of the development of student identity and academic trajectories. In the next session, the facilitators promoted an activity in which participants were asked, in groups, to reflect upon previously assigned readings (Brookhart, 2008; Hattie, 2009; Wiggins, 2012). A teaching simulation activity followed in which participants acted as students and then, using a checklist, analyzed teacher (session facilitator) performance in terms of feedback used. As an autonomous assignment, participants were requested to observe a class and write a critical analysis of the feedback used.

The focus of the third session included teaching how to think and relations between different types of feedback and the mental processing they promote in students. As an

autonomous assignment, participants were requested to create an activity that would promote student awareness of their own thinking processes during a learning task and apply it in one of their classes.

The fourth session was focused on effective feedback practices according to the models of Hattie and Timperlay (2007) and Brookhart (2008). After this discussion there was a practical application in small groups, where two members of the group performed a task, while another element, acting as teacher, guided the task implementation. Other group members observed and took notes about this interaction. As this session's assignment, participants observed a colleague's class, and completed a checklist about the feedback types, strategies and contents they observed.

The fifth session was developed around non-verbal feedback and included role-play activities and discussions about the importance of its application in the classroom, specifically in teacher-student relations and in student-student relations in the context of cooperative work. Self- and hetero-observation of non-verbal feedback was encouraged in the autonomous assignment.

The sixth session, which is the basis for this paper, consisted of implementation of an activity based in a real-life problem taken from a familiar, every-day life context and was aimed at describing and understanding in what ways this kind of activity can facilitate the teacher's use of effective feedback in the sciences classroom.

### b) Participants

Eleven teachers (ten women), from a school in the greater Lisbon area, participated in session six. Participants (mean age 44 years) had more than five years of teaching experience and were from diverse curricular areas including, Mathematics, Physics, and Chemistry. Students of these teachers ranged from the 7$^{th}$ to the 11$^{th}$ grade, and are typically between 12 and 17 years of age.

### c) Material

A problem-solving activity was devised with the intention of promoting critical thinking and motivating the workshop participants. The problem was designed so as to be (a) based on a real-life situation; (b) related to simple scientific concepts dealing with everyday human experience; (c) open-ended, appealing and creative; and (d) easily implemented. Material and equipment necessary to accomplish the activity were provided to the participants and included lamps, electrical plugs, supports, rulers, and small samples of window frame material of different colors. The activity is described in detail in the *Procedures* sub-section.

Two data collection tools were used. Participants' opinions about the nature of the performed activity were collected through the checklist *Nature of the Activity* (NA), adapted from Fiuza (2010), consisting of 15 items intended to verify if the activity performed was perceived as a real-life problem or a routine exercise. Each item was a simple affirmation of a characteristic of real-life problems or routine exercises (for example, 'In this activity: they asked us to plan experiments; they asked us to execute specific procedures'). These questions were answered on a simple dichotomy, 'yes' or 'no'.

Perceived feedback was measured based on the five dimensions of feedback previously synthesized: (a) *Timely* (Was feedback given immediately or slightly after performing the tasks?); (b) *Likely to be used* (Was feedback actionable while it was possible to act based on it? Was it given informally, during the observation of the performance?); (c) *Tangible and Transparent* (Was the feedback given on topics directly relevant to the activity? Was it enough to continue the activity without help from the teacher? Did it promote understanding of the connections between ideas?); (d) *Goal-referenced* (Did the feedback compare the

performance with the pre-established learning goals? Did it include alternative strategies for achieving the goals?), and; (e) *Consistent* (Did the feedback describe what was done right? Did it suggest what could be done to improve?). Perceptions of the feedback received were coded in three categories: frequently, sometimes, and rarely.

d) **Procedures**

The activity, based on Fiuza (2010), is centered on environmental sustainability and, more specifically, color choices and their possible effect on home temperature and comfort. Participants, divided in three small groups, were given the following instructions:

> Materials commonly used in house construction, such as window frames, influence the temperature inside our homes. Making a reasoned choice about the color of frames for our windows and doors is a way to optimize comfort and contribute to environmental sustainability.
>
> 1. Write a plan for conducting one or more experiments that will help you decide which frame materials are the most suitable for windows and doors of a dwelling. (Some material and bibliography are provided for this purpose).
> 2. Before conducting the experiments, think carefully and confirm that your planning will enable you to effectively select the most appropriate window/door frames.
>
> 2.1. If you decide to change anything, reformulate the initial plan by including the proposed changes.
>
> 2.2. Justify the proposed changes.
>
> 2.3. If no changes are proposed, write a justification for your decision.
>
> 3. Conduct the experience(s) that you planned and take notes.
> 4. Describe the procedures you followed.
> 5. Record the data, including any observations about the results.
> 6. Organize the data in a way appropriate for the purpose at hand.
> 7. Analyze the data. What are your conclusions?
> 8. Explain how the conclusions relate to the purpose of the study and the data collected.
>
> Note: In each group, the observer records feedback presented by the workshop facilitator.

While performing the activity, the participants received feedback from the session facilitator and from their peers. Having finished their group work, participants responded individually to the two data collection tools, indicating their perceptions of the feedback received, and their opinion concerning the nature of the performed activity.

At the end of the activity, a group discussion was conducted, which included: (a) exposition and justification of the conclusions; (b) discussion of the nature of the activity performed; (c) the strategies of the feedback received; and (d) reflections about how the nature of the activities can promote the use of effective feedback.

## FINDINGS

### a) Participants' opinions about the activity performed

Complete data were available from 10 of the 11 participants. Responses to the *Nature of the Activity* checklist were nearly unanimous in considering that the activity demonstrated characteristics of a real-life problem. The participants reported that (a) they were asked to plan; (b) they were provided with diversified sources of information for research; (c) they

were confronted with a problem-based question to solve with the help of bibliography and other materials; (d) they were asked to frame problem-solving methodologies; (e) they were encouraged to find out relevant information to carry out the work; (f) they were challenged to find out what they needed to do and to deal with real-life materials. The exceptions to these unanimous opinions were found in three answers, in which participants reported that they were not asked to select appropriate materials to carry out the work.

When asked if they were performing tasks with characteristics of routine exercises, ten participants reported that they were asked neither to perform previously planned work nor to observe and record demonstrations made by the facilitator. More than half of the participants (eight) answered that they were not asked to perform described procedures. Seven indicated that the basic theoretical knowledge to carry out the work was not transmitted in advance and that lists of the work material were not provided. Half of the participants (five) specified that they were instructed about which procedures to follow, and fewer than half (three) declared that they were not given instructions for the next steps while the work was being performed.

### b) Participants' perceived feedback

Complete data about the feedback perceived were available from 9 of the 11 participants. Table 1 presents the frequencies of the participants' perceptions of the feedback received according to the three categories: frequently, sometimes, and rarely.

**Table 1.** *Perceived feedback in five dimensions*

| | | Perceived | | |
|---|---|---|---|---|
| Dimension | | Frequently | Sometimes | Rarely |
| Timely | Immediate | 5 | 4 | -- |
| | Slightly after performance | -- | 9 | -- |
| Likely to be Used | While could Act | 2 | 7 | -- |
| | Informally | 7 | 1 | -- |
| Tangible and Transparent | Topics Direcly Related | 9 | -- | -- |
| | Enough to Carry on | 9 | -- | -- |
| | Understand Connections | 6 | 2 | 1 |
| Goal Referenced | Compare Performance with Goals | 8 | 1 | -- |
| | Alternative Strategies | -- | 5 | 4 |
| Consistent | What was done right | 4 | 5 | -- |
| | How to improve | 3 | 3 | 3 |

A preponderance of reported perceptions indicates that feedback types were experienced 'frequently' or 'sometimes'. The most often perceived feedback was in the *Tangible and Transparent* dimension, followed by the performance/goal comparison within the *Goal-referenced* dimension. The least reported types of feedback involved *Alternative Strategies* and indications of *How to Improve.*

## DISCUSSION AND CONCLUSIONS

The data show that during the session, effective feedback was frequently perceived by the participants while performing the activity. But might this feedback have been facilitated because the activity performed was intentionally devised and implemented as a real-life problem? Results point to the acceptance of this reason as a plausible explanation.

Since the activity is an open-ended problem embedded in a real life situation, it did not include completely defined objectives. All the necessary steps towards resolution of the task were not familiar to the participants and more than one solution was acceptable. As the participants reported, they were asked to define the problem and to plan experiences; so they had to ask each other, and the facilitator, questions that naturally emerged. Therefore, we can infer that participants were required to use their critical thinking skills.

Implementing strategies based on real-life problems is a powerful strategy to enhance the performance on problem solving in the sciences classroom (Caillot, 2006). According to Akçay (2009), 'this approach lets students improve their critical thinking skills, analyze and solve complex, real-life problems, work cooperatively in groups, and communicate orally and in written form' (p. 26). Also, results indicate that tangible and transparent feedback was frequently received from the facilitator and peers during the performance of the workshop activity. This means that participants' perceived feedback was given to them about topics directly related to the activity performed, was enough to carry on the work and allow them to realize connections between ideas. Yet feedback was frequently perceived as goal referenced. That is, learning goals were compared to the work in progress, although alternative strategies for achieving the goals were sometimes, or rarely, included. This perception may be due to the facilitator avoiding the suggestion of specific procedures to be followed. This could also explain why all participants reported having perceived that feedback on what they could have done to improve was given only sometimes or rarely. Feedback describing what they had done right was perceived as happening frequently or sometimes.

Teachers' perceptions about the innovative nature of the activity proposed and the feedback received may have been influenced by their previous beliefs and conceptions.

In the group discussion that took place in the final part of the session, three participants reported that since only the necessary materials to carry out the activity were available, they had no choice to decide about adequate equipment. These teachers considered that the provision of the necessary material on a table was equivalent to presenting a list. This is probably why they answered that lists of the material were provided to them.

Also, some participants declared that they interpreted the feedback received as continuous instructions to proceed with the work. This may explain why seven participants reported that instructions about the next step were given to them during the activity. After reflection, these participants recognized that the feedback received encouraged them to find out what to do, rather than instructing them.

Half of the participants identified the script of the activity as a recipe protocol of procedures to follow, a teaching strategy often used in the sciences laboratory classroom (Kyle, Penick, & Shymansky, 1979; Lunetta, 1998; Roth & Roychoudhury, 1993). Therefore, the differences between a script and a recipe protocol were debated and clarified.

Sessions that diffuse educational strategies which include reflection about science teaching practices, related with critical thinking, and with effective feedback, can be useful in promoting teachers' reflection, leading them to rethink and develop new conceptions and beliefs towards the goals for science teaching and learning. The results of this study, although limited by the number of participants and the brevity of the intervention, reinforce the idea that activities drawn from a familiar, every-day life context and based on real-life problems, that intentionally stimulate the use of critical thinking skills, enhance science learning. The implementation of such activities encourages students to define problem-solving methods, to

pursue and assess solutions, and to seek the feedback they need to accomplish their work and move their learning forward. Furthermore, this science teaching strategy, based on the implementation of such an activity seems to have facilitated the provision and perception of feedback that is timely, likely to be used, tangible and transparent, goal-referenced and consistent.

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