PROMOTING STUDENTS’ CRITICAL THINKING THROUGH THE DESIGN OF SCIENTIFIC RESEARCHES RELATED TO A SSI: THE CASE OF ADHD

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Abstract: Providing students with the opportunity to discuss or debate controversial SSI gives them the chance to develop skills associated to critical thinking. This study is part of a project that investigates the promotion of these skills by engaging students in the analysis of the reliability of different scientific studies related to a SSI. In order to collect research data, an activity based on the Attention Deficit Hyperactivity Disorder (ADHD) was designed and carried out in five secondary schools where 291 students aged 14-15 and 16-17, participated. One part of this activity was asking the students to design a scientific research to study whether the use of stimulant medications to treat ADHD increases the risk of substance abuse in adulthood. In this paper we analyze the scientific researches proposed.

Observing the students’ proposals we classified the researches depending on the objective, the methodology followed (observational or interventional) and the sampling of the study (use of control groups or the presence of a description of the sample). We describe the collected data and compare them between students of different ages and different specializations in their education. By performing Chi-squared tests we determined whether the differences found were significant. On the one hand, attending to the age of the students we found significant differences in the methodology proposed. Although observational studies were always preferred, interventional studies appeared much more frequently in older students. On the other hand, we divided the students between 16 and 17 years old into scientific or humanistic students depending on their education specialization. Attending to this division, we found significant differences in the methodology and the sampling method. Students with a predilection for science proposed interventional studies more and mentioned control groups much more frequently than student of humanities. Implications for research are discussed.

Keywords: Socio-scientific Issue, critical thinking, design of scientific researches, Secondary school, ADHD

INTRODUCTION

Background and rationale
Critical thinking is frequently conceptualized as one of the goals of science education (Bailin, 2002). By broad definition it is a form of reflective thinking that ultimately helps one to decide what to believe or do (Ennis, 1996). It is related to many functions including evaluating the arguments of others, evaluating one’s own argument, resolving conflicts and understanding resolution. Behind the promotion of these skills, there is the need of analyzing information properly, developing criteria for choosing amongst conflicting views (Norris & Korpan, 2000) and developing skills in handling information for disentangling opinions and interpretations from facts (Tytler et al., 2000). In order to promote and develop such critical thinking skills, Socio-scientific Issues (SSI) can be used.

During the recent past, SSI have been introduced in science classrooms and also investigated by science education researchers (Albe, 2007). SSI relative to health, environment, and techno-scientific innovations are defined as social dilemmas linked to science about which citizens have to make decisions (Molinatti et al. 2010). These issues are multi-faceted, address real world issues and expose students to problems that involve a number of discrepant scientific, social or moral viewpoints (Ratcliffe & Grace, 2003). Hence, SSI are said to be vehicles, not only for raising students’ interest in science, but also for enacting scientific practices and critical thinking and strengthening generic skills such as team-work, problem-solving or media literacy.

It is important to highlight that SSI appear almost daily in the mass media. Notice that, nowadays, the media (newspapers, magazines, television, radio and the Internet), taken as a whole, are considered “the most easily accessible sources of scientific information to the general public” (Lewenstein, 2001, p. 30). Nelkin (1995) declared that: “For most people, the reality of science is what they read in the press” (p. 2). In her opinion, the media represent the only contact that most of the population have with the rapidly changing fields of science and technology, as well as a major source of information on the social implications of these changes. Even citizens with a scientific or technological background are incapable of following the specialized literature of all scientific fields, resorting to the media to stay informed about scientific progress outside their specialty (Bauer, 1992). However, sometimes the media present a sensationalist image lacking in rigor and stereotyping science and scientists (Nelkin, 1995). Moreover, it usually confronts citizens with science that is different from the one that is usually introduced in science classes since the news in the media highlight a “borderline science” that is controversial, preliminary and under debate (Zimmerman et al. 1999). All those media influences stress the need of schools promoting the discussion of students’ conceptions about the interactions between science, technology and society (Reis & Galvao, 2009) and the development of critical thinking skills.

Kolsto (2001) points out that one of the main frustrations mentioned by lay people trying to form an opinion and to understand discussions concerning SSI is the perceived disagreement among different scientists and institutions. The results reported in his study showed that students interpret such disagreements in terms of interests, personal opinions and incompetence related to scientists. From our point of view, these interpretations and the difficulties of students when dealing with uncertainty regarding to SSI are due, among other aspects, to students’ conceptions about the processes of science and its epistemic base.
According to scientific literacy “students are expected to develop an understanding of the epistemology of scientific knowledge as well as the processes and methods used to develop such knowledge” (Zeidler et al, 2005, p.358). An important principal of the scientific enterprise is that scientists share their evidence with the scientific community and they can evaluate one another’s explanations. Science is a social activity and scientists’ theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations often influence their work (Lederman et al, 2002). Despite this, most formal science education focuses on a conventional, non-controversial, established and reliable science. As a consequence, students tend to come up with the idea that science is a collection of facts and theories based on experiments that yield an exact result when they are well done or carried out by scientists from the same field of knowledge (Etkina, Murthy, & Zou, 2006; Kung & Linder, 2006; Rollnick, Lubben, Lotz, & Dlamini, 2002). These differences between the science reported in the media and the one that is usually presented in science classes could be another one of the reasons why students have difficulties dealing with uncertainty and with scientific disagreement related to SSI.

Therefore, we believe that it is important to provide students with a more realistic image of science in their classes. This means engaging them in scientific practices and promoting critical thinking skills. Understanding that science is a human activity, that scientific knowledge is tentative and that scientists continually test and challenge previous assumptions and findings, may help students to understand scientific disagreement. With this goal in mind, incorporating the analysis and discussion of scientific studies in science classes may be a useful tool in order to help students to understand how scientific knowledge is produced.

This paper reports part of a thesis project focused on the promotion of critical thinking skills by engaging students in the analysis of the reliability of different scientific studies related to a SSI. The first phase of this research consisted on introducing the SSI to the students, discussing all the controversies related to it and then asking them to describe which researches could be done in order to contribute to find out new scientific knowledge related to one of the controversies presented. In this paper we describe and analyze the researches proposed, highlighting some of the research implications.

Objective of the research

Bearing in mind the background and needs just presented, in this study we address the following research objectives:

1) To describe which are the research objectives that students proposed in their studies.
2) To analyze which aspects concerning the methodology of the studies were described by the students.
3) To explain which aspects of the sample were described by students.
4) To find out if there are significant differences in the students’ proposed studies according to their scientific knowledge and age.

METHODOLOGY

Data collection
In order to achieve the objectives previously explained, a classroom activity was designed and carried out in 5 secondary schools from February to June 2012, in Barcelona (Spain).

A total of 291 students took part, 58 students aged 14 to 15 and 233 students aged 16 to 17. The elder students were in post-compulsory secondary education and this was the first year that they had to choose a scientific, social or humanistic specialization in their studies. These ages were chosen because the topics related to the SSI selected are dealt with for the first time in the curriculum at 13-14 years-old and for the last time at 16-17 years-old, for students who chose the scientific option (81 students in our case).

In the case of the 14-15 years-olds, the activity was carried out in science class. For the rest of the students it was part of a science course within the core curriculum. This course covers the study of current scientific problems or events with an emphasis on argumentation and is basically a course that imparts scientific information. The research data was assessed from classroom products including worksheets and field notes from the classroom observation.

The SSI selected
The SSI selected was the controversy related to stimulant treatment for Attention Deficit Hyperactivity Disorder (ADHD) was the SSI selected.

ADHD is one of the most common neurobehavioral disorders of childhood. It is a group of behavioral symptoms characterized primarily by the co-existence of attentional problems and hyperactivity, with each behavior occurring infrequently alone and with symptoms starting before seven years of age. ADHD, its diagnosis and the use of stimulant medication in its treatment is considered controversial since the 1970s. Since ADHD is usually reported in the media and paying special attention to the fact that the percentage of children with an ADHD diagnosis continues increasing, we considered that helping students to understand the controversies related to it was relevant. Therefore we thought that using the controversy related to its treatment was a suitable tool for engaging students in designing scientific researches.

The activity designed
The activity lasted 2h and was divided into two one-hour sessions. At the first session, ADHD was introduced as a SSI by listening to a radio program where different stakeholders implicated in this disorder explained their knowledge and experiences related to it. After that, students analyzed the viewpoints of various stakeholders and read information about different controversies regarding ADHD such as its definition or cause, its diagnosis and its treatment. Then, at the second session, since one of the stakeholders talked about the disagreement of health professionals about the effectiveness of the stimulant used to treat ADHD, students read information about this stimulant (Methylphenidate) paying special attention to its use and adverse effects (see Figure 1).

Once students had read this information and discussed it with the whole class following the guidance of the teacher, they were introduced to one of the most controversial issues in child psychiatry: whether the use of stimulant medications to treat ADHD increases the risk of substance abuse in adulthood (Wilens et al., 2003).
All stimulants work by increasing dopamine (a brain chemical, or neurotransmitter, associated with pleasure, movement, and attention) levels in the brain. The therapeutic effect of stimulants is achieved by slow and steady increases of dopamine, which are similar to the natural production of the chemical by the brain. The doses prescribed by physicians start low and increase gradually until a therapeutic effect is reached. However, when taken in doses and routes other than those prescribed, stimulants can increase brain dopamine in a rapid and highly amplified manner (as do most other drugs of abuse) disrupting normal communication between brain cells, producing euphoria, and increasing the risk of addiction (Centers for disease control and prevention, 2005).

![Methylphenidate binds to nerve terminals](image)

**Figure 1.** The effects of stimulants in the brain.

Teachers explained that although latest research far suggests that individuals with ADHD do not become addicted to their stimulant medications when taken in the form and dosage prescribed by their doctors, and that several studies report that stimulant therapy in childhood does not increase the risk for subsequent drug and alcohol abuse disorders later in life, there are studies that report opposite results. Assuming the need of carrying out more research, students were asked to design a scientific research aimed to find out whether people treated with Methylphenidate have an increased risk of suffering substance abuse disorders (see Figure 2). We analyze students written responses.

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**... and what do scientific studies report about this issue?**

The results of several scientific studies reveal that Methylphenidate increases the levels of dopamine in the brain. Furthermore, some of them also point out that Methylphenidate possesses some structural and pharmacological similarities to cocaine. By referring to these two aspects, there are scientists who warn that people treated with this stimulant have an increased risk of suffering substance abuse disorders in their life. The effects of long-term Methylphenidate treatment on the brain development of children with ADHD is still a subject of study and debate.

*Taking this information into account, describe a scientific research that could be conducted in order to find out whether people treated with Methylphenidate develop an increased risk of substance abuse.*

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**Figure 2.** Question about the design of a scientific research proposed.
Data analysis

According to other studies (Oliveras et al., 2011; Wu & Tsai, 2007) and to our research goals, students’ proposals were analyzed following qualitative methods combined with quantitative parameters of analysis. Students’ responses were read in order to take preliminary notes regarding patterns emerging from data that were then compared with categories obtained in other studies. Then, frequency of responses within each category was calculated with the support of Atlas.Ti. Finally, credibility and trustworthiness was established through independent examination of data by several investigators and through triangulation of data.

RESULTS AND DISCUSSION

In this section, results are organized by objectives.

1) **To describe which are the research objectives that students proposed in their studies.**

In their proposals, most students (83.2%) aimed to analyze the relationship between being (or having been) treated with Methylphenidate and the development of drug addiction. They tried to explore whether the fact of taking this medicine increases either, the predisposition to consume drugs or the degree of dependence on substances such as alcohol, tobacco or cocaine. This means that most students focused on analyzing the specific problem presented to them.

Other students also referred to the scientific knowledge previously discussed by proposing to analyze in depth the stimulant used in ADHD treatment (13.7%) or the secretion of Dopamine in the brain (2.4%). Whereas the first ones focused on studying Methylphenidate with the aim of better understanding how this medication acts in our body, which are its side effects and whether people treated with it become addicted to it; the second ones focused on studying in depth the secretion and action of dopamine in the brain, since this brain chemical is related to the action of drugs and to the treatment of ADHD. Another aspect to be pinpointed is that there were also a few students (0.7%), all of them aged 16-17, who suggested the development of researches for new drugs in order to investigate new ways to treat ADHD or to reduce the side effects caused by the current treatment.

2) **To analyze which aspects concerning the methodology of the studies were described by the students.**

The results illustrated in Table 1 show that whereas there are students who do not explain the methodology of their proposals (usually they just mention the research objectives of their studies), most of them provide details of the methodology of their researches. In this latter case, they mainly refer to two different aspects. The first one is related to the strategies followed in order to collect research data, for instance, observations, analysis or monitoring different aspects of the experiment and the second one is related to the way the researchers behave when conducting the study. In accordance with a common way of classifying clinical trials, the methodologies described by students have been categorized
in observational or interventional studies. An observational study is one where the researchers do not actively manage the study, while in an interventional one, the researchers manage the study by providing participants with drugs or medicines. Examples of both kinds of studies can be found in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Kind of methodology</th>
<th>Exemplars</th>
<th>%</th>
</tr>
</thead>
</table>
| Methodology is not described | **E1**: “...will investigate the adverse effects of Methylphenidate”  
**E2**: “...will find out if the stimulant increases brain dopamine”  | 3,8 |
| Observational methodology | **E3**: “...we will give questionnaires to people suffering from ADHD asking about the consume of substances such as tobacco, alcohol and cocaine. We will sample people under medication and people who do not take medication for the disorder. After this, we will compare the results obtained...”  
**E4**: “...to ask drug addicts whether they had been diagnosed from ADHD and medicated with Methylphenidate. Calculating and comparing the percentages obtained...”  
**E5**: “...We control the levels of dopamine secreted of a healthy person, a drug addict and a person suffering from ADHD that is under medication. We compare these levels and if the ones of the medicated person and the drug addict are similar, we will consider that the Methylphenidate is a drug...” | 65,3 |
| Interventional methodology | **E6**: “...we make 3 groups. One group is provided with the treatment continuously in a long-term basis, another is provided with the treatment sporadically and the last group is given a placebo. When they reach adolescence, we facilitate them the access to addictive substances and observe whether the medicated groups are more likely to consume them....”  
**E7**: “...we divide the people participating into two groups. Only one group is given Methylphenidate. After 3 months we analyze which persons have consumed drugs”  
**E8**: “...we pick a subject and provided them with a drug, another subject is given Methylphenidate and another subject is given both, the drug and the Methylphenidate. We perform an analysis to see which differences are observed in each case...”  
**E9**: “...we hide Methylphenidate in an edible that the patients with ADHD participating in the experiment dislike and analyze whether they start liking the edible and if they want to eat more of it when the medicament is present in it....” | 30,9 |
These results reveal that students are able to describe the methodology they would use in order to collect data and to state the role that researchers should play when conducting the study. However, they do not mention anything about the specific variables they will analyze, how and when they pretend to analyze them or the need of guaranteeing the reliability and the reproducibility of their studies. Finally, we would like to pinpoint that there were students who proposed creative researches (see exemplar E9) and others who did not take into account ethical aspects that should be intrinsic to scientific researches (see exemplar E8). In our opinion, exemplars like these should be shared with the whole class in order to promote discussions about the role of creativity in scientific knowledge development and the need of guarantying ethical conducts.

3) To explain which aspects related to the sample were described by students.

The analysis of students’ responses show that there are students who:

a) Do not provide details about the participants of their studies

b) Provide details of the subjects that would be involved in the study: the number of patients enrolled in the study, their age or their specific health conditions (for example whether the participants suffer from ADHD, whether they are or have been under stimulant medication, or whether the participants suffer from any kind of drug or alcohol abuse disorders).

c) Provide details of the subjects that would be involved in the study and also establish the participation of control groups. Students refer to the participation of two different types of control groups:

a. Control 1: the study involves subjects with and without ADHD.

b. Control 2: the study involves subjects diagnosed with ADHD who are (or have been) treated with stimulant medication and subjects who have never been treated with it.

Table 2 shows the percentage of students that referred to each of these categories. As it can be seen, almost half of the students provide details of their sample but do not include the participation of control groups. Students who defined control groups mostly identified the need of including control 2 or both controls 1 and 2 groups.

Table 2
Distribution of the studies regarding their sampling.

<table>
<thead>
<tr>
<th>Details of the sample provided by the students</th>
<th>Percentage of students that referred to it</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Sample is not described</td>
<td>21,5</td>
</tr>
<tr>
<td>S2 Sample is described without including the participation of control groups</td>
<td>42,6</td>
</tr>
<tr>
<td>S3 Sample is described including the participation of control groups</td>
<td>36,0</td>
</tr>
<tr>
<td>S31 Students referred only to control 1</td>
<td>2,8</td>
</tr>
<tr>
<td>S32 Students referred only to control 2</td>
<td>19,7</td>
</tr>
<tr>
<td>S33 Students referred to control 1 and 2</td>
<td>13,5</td>
</tr>
</tbody>
</table>
4) To find out if there are significant differences in the students’ proposed studies according to their scientific knowledge and age.

In order to analyze the possible influence of students’ age or specialty on the type of studies proposed, we compared the data using Chi-Squared Tests. In this section, we will describe the significant differences observed in our research. A difference is statistically significant when the p-value of the test is less than 0.05. When defining the objectives of their researches, no significant differences are found in terms of age or specialty of the students. However, when dealing with the methodology proposed, we found significant differences between students of different ages (p-value = 0.0006) and between students with different specialties (p-value = 0.0012). Although observational methodology is always preferred, older students choose interventional studies much more frequently than younger ones and students with a predilection for science choose interventional studies much more frequently than students with a predilection for humanities (see Table 3).

Table 3

*Distribution of the studies regarding the methodology followed depending on the age and specialization of the students.*

<table>
<thead>
<tr>
<th>Kind of methodology described by students</th>
<th>Percentage of students considering…</th>
<th>Taking science options</th>
<th>Taking humanities options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methodology is not described</td>
<td>aged 14-15</td>
<td>3.4</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>aged 16-17</td>
<td>3.9</td>
<td>60.1</td>
</tr>
<tr>
<td>Interventional methodology</td>
<td>86.2</td>
<td>49.1</td>
<td>36.1</td>
</tr>
</tbody>
</table>

With respect to the details that students provided about the sample, although the description given by the students does not differ significantly depending on their age, when focusing in the oldest students (aged 16-17), we found significant differences (p-value = 0.0005) between the students who chose a scientific option and those who chose a humanistic option in their education. Most of the students taking science options mentioned the participation of control groups whereas only a third of students taking humanities options referred to them (see Table 4).

Table 4

*Distribution of the studies regarding their sampling depending on the age and specialization of the students.*

<table>
<thead>
<tr>
<th>Details of the sample provided by students</th>
<th>Percentage of students considering…</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Taking science options</td>
</tr>
<tr>
<td>Sample is not described</td>
<td>12.7</td>
</tr>
<tr>
<td>Sample is described without including the participation of control groups</td>
<td>30.9</td>
</tr>
<tr>
<td>Sample is described including the participation of control groups</td>
<td>56.4</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND IMPLICATIONS

The results of the present research suggest that engaging students in the designing of scientific researches allow teachers (and researchers) to detect different ways in which students understand scientific practices.

When explaining their proposals, students mostly described observational and interventional studies. The kind of methodology proposed depends on students’ age and on their scientific knowledge, since students aged 16-17 and students taking science options described more interventional studies than the rest. From our point of view, these results show that being familiar with the scientific methodology may help students to design scientific researches. This means that more attention should be paid into explaining science-in-the-making to all students, not only the ones that would study scientific careers. In accordance with this need, our results also reveal that students’ scientific knowledge influence the definition of control groups of participants when describing the sample. Students tend to provide sampling details such as the number of patients enrolled in the study, their age, and their specific health conditions, but only students taking science options tend to include the participation of control groups in their studies. Hence, the need of defining control groups in a research should be discussed with all students.

Our results show that there is a need to guide students and promote their participation on whole-class discussions conducted by the teacher in order to help them think about all the aspects that should be taken into account when designing scientific researches. Science affects and is affected by various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy and religion (Lederman et al., 2002). All these background factors form a mindset that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they interpret their observations (Lederman et al., 2002). Therefore, it is important to engage students in activities that allow them to put in practice all this knowledge and that help them identify the main aspects of a scientific research. With such activities, for instance, students would become capable of understanding the relevance of defining control groups and of assuring the reliability and the reproducibility of their studies. Furthermore, it is also relevant to help them realize that guaranteeing ethical conducts and avoiding the influence of financial interests are key when conducting scientific researches. Thus, by designing researches and discussing about them, students may develop abilities in analyzing and evaluating data, and, consequently, critical thinking skills would be promoted. Finally, it is important to state that objectives related to critical thinking and to working with SSI cannot be achieved in a single activity or unit but rather by being included regularly in science classes.

Notes

1 By using the term “Scientific practices” we are referring to “the specific ways members of a community propose, justify, evaluate, and legitimize knowledge claims within a disciplinary framework” (Kelly, 2008, p.99).

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REFERENCES


