

Consensus among experts on the state of the art of science education research

Consenso entre expertos sobre el estado del arte de la investigación en la didáctica de las ciencias

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Abstract

The review of two of the most relevant research topics in the field of science education: conceptual change and alternative conceptions, shows a series of methodological and theoretical weaknesses which concord with the ones indicated by expert-led seminars. The weaknesses suggest that there are other less rational commitments which explain the heavy production of writings in the field. Our research examines these phenomena and concludes by giving suggestions for progress. We also present a proposal which may contribute to overcoming the deficiencies identified.

Key words: *conceptual change, alternative conceptions, research topics (lines of research) in science teaching.*

Resumen

Revisión de dos de las líneas de investigación más relevantes en el ámbito de la didáctica de las ciencias: cambio conceptual y concepciones alternativas, muestra una serie de debilidades metodológicas y teóricas que son las mismas que se señalan en seminarios de expertos. Las debilidades sugieren que existen otros compromisos menos racionales que explican la fuerte producción de trabajos en el ámbito. Nuestra investigación examina estos fenómenos y finaliza dando sugerencias para el progreso. También presentamos una propuesta que pueda contribuir a la superación de las deficiencias identificadas.

Palabras clave: *cambio conceptual, concepciones alternativas, líneas de investigación en enseñanza de las ciencias.*

INTRODUCTION

In some recent forums and expert-led seminars, the current situation of science education (SE) as a field of knowledge has been evaluated. We focus our interest on two reports that have been published:

- CACHAPUZ, et al. (2004). These authors are the organizers of the International Seminar on the Present State of Research in Science Education, which was carried out on the 15th and 16th of October, 2004 at the *Universidade de Aveiro* (Portugal), where important experts from all over the world participated, among whom it is worthy of mentioning, among others, in alphabetical order: DUSCHL, R.; GIL-PÉREZ, D.; IZQUIERDO, M.; JENKINS, E. W.; MATTHEWS, M. R.; OSBORNE, J.; SEQUEIRA, M. C.; WHITE, R., etc.
- MOREIRA (2005). This work brings together the conclusions and recommendations of experts who met in the *Encuentros Iberoamericanos sobre Investigación en Educación Básica* [Iberoamerican Meetings on Basic Education Research] (Burgos, Spain), in 2002 and 2004. The main senior research in this seminar was ANTONIO MOREIRA as well as a group of Iberoamerican researchers.

The writing styles of the seminar reports are quite different. While in the Aveiro report suggestions and directions for improving weaknesses are given, the Burgos report has a more explicit and direct style, exposing the multiple weaknesses in the SE field. Yet, in spite of the difference in styles, both reports present notable coinciding observations on three important aspects of SE field. We will enumerate below, first, the opinion of the Aveiro seminar and, secondly, that of Burgos, on each topic.

1. The body of knowledge

- As of now a theory or cohesive consensual framework in the field of Science Education does not exist, and it seems to be quite improbable that it would come to be formulated soon. However, it's important to move towards the search for a global accord, for which science educators shall have to develop a specific and coherent body of knowledge.
- The majority of research lacks a coherent and consistent theoretical framework. That is, theoretical references, when they are pre-

sented, are not articulated either with empirical data or with the analysis of such data. Theoretical references are imported, sometimes in a non-critical manner, that is to say, without reconstruction or adjustments made for suitability in the SE field.

2. Research

- We shall have to establish priorities for SE research, according to relevance for solving real problems and contribution to the construction of a more coherent body of knowledge. The area, which is in rapid growth, should consider more the topic of quality. With that end in mind, researchers will have to maintain a spirit of critical review.
- Few lines of research are progressive and many are planned just for the short term. Lots of hurried and low-quality production exists, which are more of an application than a production of knowledge. The methodological instability is high in qualitative as much as it is in quantitative focuses. The research still does not have a real impact on educational practice. The area researchers do not accept critiques well, nor do they do them themselves. There is a lack of a tradition for critique in SE research.

3. The SE community

- The community should be organized in multidisciplinary research networks, national as well as international, with the goal of improving the relevance, the quality and the visibility of the research. These networks should work at increasing communication among professors and researchers by means of additional means, and not simply publications.
- The community shows significant weaknesses, given that few groups and societies exist. The journals do not have clear criteria or objectives in peer review. There are few strong programs for training. Instead, a light incorporation of researchers from other areas exists, and these do not have sufficient training in SE field. Furthermore, there is a lack of visibility because of the influence of other areas of research and those organizations responsible for educational politics. Finally, little dialogue and interaction is apparent among SE communities.

An interesting exercise is to compare some of the coinciding observations which were stated in the expert forums on the state of the art of SE with some academic reports published in the last 2 decades. The purpose of this article is to contribute some additional elements to those set forth in the expert forums. Ours are intended to help readers to understand the magnitude of the present academic difficulties in SE research.

FOCUSING ANALYSIS IN TWO OF THE MOST INFLUENTIAL RESEARCH LINES IN SE

The literature reveals a significant group of reviews related with two of the most influential research focuses in the SE field, namely: conceptual change (CC) and alternative conceptions (AC). Both research lines contain a sample of empirical works which make use of quantitative and qualitative methodologies and both represent a quarter of the publications in the field of SE (TSAI & WEN, 2005).

In terms of the samples of articles employed, this study carries out a partial analysis of other reviews, 6 done by the authors and 1 by GUZZETTI (GUZZETTI, et al. 1993). Directly and indirectly, eliminating repetition, a sample of more than 200 papers has been analyzed. The studies, from each of the two areas of research, are:

- Reviews on CC: GUZZETTI, et al. (1993); SOTO, OTERO and SANJOSÉ (2005) and MARÍN (1999). These writings bring together international

research production from the 80s and 90s. They focus on experimental group research reports and the composition of the SE international community. They deal with topics related to the theoretical and methodological focuses of the CC research area.

- Reviews on AC: MARÍN and JIMÉNEZ-GÓMEZ (1992); JIMÉNEZ-GÓMEZ, SOLANO and MARÍN (1997); MARÍN, SOLANO and JIMÉNEZ-GÓMEZ (2001); MARÍN, JIMÉNEZ-GÓMEZ and BENARROCH (2004). These projects were carried out in the last 15 years and review more than 100 works on AC, on distinctly scientific issues.

THE MOST RELEVANT CONCLUSIONS OBTAINED IN THE RESEARCH CITED ON CC

The three review research papers on CC coincide in highlighting the following four critical points:

1. The majority of the writings lacks a model or reference theory to give a basis to the research. In the identification of the main foundations which guide CC research, it is found that 2/3 of the works do not follow any theoretical model. Furthermore, it is proven that a similar fraction declare that they follow a model or a theory while making no real commitment is found in the decision making of the different phases of the research (SOTO, OTERO and SANJOSÉ, 2005).
2. There is excessive individual production which is both atomized and fragmented. The bibliometrical study of cross references shows that the connections among writings is very weak, in fact, it is not common for authors to quote previous studies which have dealt with the same topic (SOTO, OTERO and SANJOSÉ, 2005). With that, in the majority of publications, evidence has not been found to show that authors depend on the results and conclusions of previous research (also see MOREIRA, 2005). These data are even more significant if one keeps in mind that a good part of the sample was taken out of the most influential journals of the SE field.
3. There are also decisions in what we could call "excessive quotations". In effect, it is common to see that a quotation does not proceed with the logical commitment with the quoted work. Writers tend to quote prestigious works and authors more, in order to "get on board" or to align themselves with a research framework rather than to make a real contribution to the field (DUSCHL, 1994).
4. An analysis of the *internal validity* for quantitative writings and *credibility* for qualitative works, shows that only 30.7% of the quantitative works and 39.4% of the qualitative ones possess good methodological standards (SOTO, OTERO and SANJOSÉ, 2005). This outcome is similar to the one obtained by GUZZETTI, et al. (1993), where only 25% of the quantitative works presented a high methodological quality. In that regard, JANIUK (1999) suggests that the European research in chemical education does not have quality standards, while JENKINS (2000) calls upon the SE community of researchers to review the procedures for quality control.

THE MOST RELEVANT CONCLUSIONS OBTAINED BY THE RESEARCH PROJECTS QUOTED ON AC

The AC line of research is the one which more publications have listed in the past 2 decades (MARÍN, SOLANO and JIMÉNEZ-GÓMEZ, 2001). Many papers have been published with a very similar structure: First, delimiting the conceptions of the student on the content of science which is the object of the teaching, and, secondly, from the information, proposing some pedagogical implications. This way of proceeding is called "the movement of alternative conceptions", by authors who are involved (GILBERT and SWIFT, 1985). Although afterwards the name passed through various changes (MARÍN, SOLANO and JIMÉNEZ-GÓMEZ, 1999), it seems to us that the original name is the one which best sums up its essence.

What follows is an orderly synthesis of the main AC research conclusions:

1. The academic content which attempts to know the conceptions of the student is the main reference point for seeking and interpreting data. This is the main characteristic which determines, in a great measure, the rest of the critical commentaries. However, other theoretical contexts (taken, for example, from psychology) are not used (MARÍN, 2003b).
2. A significant division exists between real supporting documents and the bibliographical supporting documents cited. In the analysis of bibliographical quotes, articles whose supporting documents formulated expectations which, in one way or another, modulated the course after the research were scarce, at 10% (MARÍN, SOLANO and

JIMÉNEZ-GÓMEZ, 2001). The typical situation is that the quotes used for giving bases to the research mean little or nothing for the latter development of the project (questionnaire design, the classification of data, the interpretation of the outcomes, etc.).

3. To analyze the validity or the viability of the information obtained by students is not common. Only the third part of the sample analyzed uses techniques for partially analyzing the degree of validity and viability of the data (MARÍN, SOLANO and JIMÉNEZ-GÓMEZ, 2001). The controls for analyzing the quality of the data should be consistent in all empirical research which presents itself as having a degree of scientific character.
4. The information (taken from the student) related to the content which is the object of the teaching is biased and limited.

POINTS OF AGREEMENT FROM THE REVIEWS AND REFLECTIONS ON THE STATE OF SE

The notable agreements among the reviews of both lines of research and the corresponding agreement of reviews with the ones obtained in the expert seminars of AVEIRO and BURGOS should not be ignored (CACHAPUZ, et al. 2004; MOREIRA, 2005).

Three general agreements are shown below, followed by others which are incomplete. In the first three, the affirmations of the seminars are shown, accompanied by the agreements in the review of the research:

1. The majority of the projects are developed without a theoretical framework and they demonstrate a deficient coordination among supporting documents and the empirical phase of the research. The data which support the reviews confirm that this is true: 68% of the works which lack a theoretical model to give a basis for the CC research; 80% of the works on AC do not use appropriate theoretical contexts. Academic content is the main reference for seeking and interpreting data. A lack of commitment exists with a firm center of research, even in the CC papers which explicitly declare that they follow such a firm center (34%).
2. A good number of works demonstrate methodological weakness, which is why a greater sense of critique and responsibility should be demanded of researchers. The CC manuscripts demonstrate mediocre methodological quality in 70% of the quantitative research writings and in close to 60% of the quantitative research writings. In AC articles, there are 67% which do not analyze the validity and reliability of the information obtained by students.
3. In the SE field, there is a manifest lack of dialogue among experts, with production being hurried, pointed and poorly coordinated with works on the same topic. In conclusion, while significant gaps between the supporting AC research texts and the ones cited in bibliographies are perceived, in the bibliometrical CC analysis, it becomes evident that an excessively individualized, atomized and fragmented production exists.

There are other agreements, but not as general as the ones which were previously expounded. For example:

1. In the BURGOS seminar, as well as in the reviews previously carried out, the use of a deficient psychological vision of the learner is critiqued. It is perceived that the learning proposal which is sustained from CC is very limited, even impossible from a psychological perspective, and that the information which is taken from the student on the content to be taught is biased and limited in AC.
2. In the BURGOS seminar and in the review on AC, accusations were raised that the research lines only demonstrate progression and that the majority of the research papers consist of application. They are not production of knowledge. On this particular point, the experts who met in the AVEIRO seminar suggested that more contributions towards the creation of an SE theoretical framework of knowledge should be made.
3. In the AVEIRO and Burgos seminars, it is affirmed that notable deficiencies exist in the formation of SE experts. This is also perceived in the review of the two lines of research which establishes that the theoretical commitment of the works evaluated is low.

SUGGESTIONS AND PROGRESS DIRECTIONS

The directions of progress should be focused on rectifying the weaknesses found, thereby taking advantage of the elements which are already established in the SE field. These directions align themselves

with the ones outlined in the AVEIRO and BURGOS seminars (CACHAPUZ, et al., 2004; MOREIRA, 2005), but they contain details, taken from the reviews of the lines of research (which have been the object of this article), which clarify matters even more:

- An intentional search for a theoretical framework for the SE field is necessary. The current theoretical elements which are the most utilized in the SE field: constructivism and the history and philosophy of science (HPS), cannot be the only candidates for fulfilling the role of a theoretical framework, for the following reasons:
 - With reference to constructivism, it has a high degree of consensus, but in its present condition, it cannot play the role of the theoretical center due to the fact that it is developed in a wide array of levels. The most agreed upon of these levels is the theoretical center called *trivial constructivism* (VON GLASERSFELD, 1991; MATTHEWS, 1994; MARÍN, SOLANO and JIMÉNEZ-GÓMEZ, 1999), whose theoretical commitment does not go beyond the affirmation that knowledge is not received passively, but it is actively constructed by the subject who knows.
 - In the case of the HPS, even supposing that a consensus were reached, it does not offer a strong enough theoretical context for giving an adequate response to the wide array of problems in SE field such as the cognitive phenomenology associated with the learner.
- Improve communication among SE experts. Work must be done in two of the directions where weaknesses have been noted:
 - Intracommunication. Currently, the interchange of contributions of experts is mainly done through journal articles or with projects presented at meetings or conferences. This system of interchange is extremely slow. More than fomenting critique, debate and learning, it serves instead to defend personal positions. Furthermore, it does not improve communication, given that data show that little is being read. Methods which are more interactive such as a seminars or workshops carried out in a conference or in a university interchange context would be helpful.
 - Intercommunication. The SE field urgently requires the scientific formation of future SE experts (GUTIÉRREZ, 1987; GIL, 1991; CAÑAL, 1995). In view of the absence of a firm center, it is no surprise that training tends to be divergent.
- Foment the spirit of friendly critique in the SE field. Although they are not common, some critical articles have appeared which contain serious proposals or which refute certain SE field content. What is the reaction or the attitude of the community in view of such a refutation? In the two research lines analyzed, the typical response is to ignore critiques or to reject them (SOLOMON, 1994; DUSCHL, 1994).

The authors argue that the key to fomenting communication and critical activity in SE is in the existence of a theoretical framework or center. Deciding upon one would have numerous positive effects:

- It would avoid turning publications in directions which, in the passing of time, demonstrate their weaknesses. Such deviance would be avoided, in part, if some of the knowledge available in other similar fields is considered (JIMÉNEZ-GÓMEZ, BENARROCH and MARÍN, 2006).
- It would give an answer to a weakness in the SE field: the unequal training of those who make up the SE field. Currently, a specific plan for training does not exist. The initial university training of the majority of SE researchers is basically in particular science subjects (DUSCHL, 1994). Consequently, the demands of the professional context obligate one to obtain additional training as an expert, generally using the material published in the field of SE. The current divergence in this material and the absence of a common theoretical center explain the unequal development of experts who are orientated by the research group in which they are registered.
- It would permit an answer to the questions surrounding the dispersion of criteria for establishing the contents of disciplines which properly belong to SE.

- It would provide an answer to the lack of identity, or, as MOREIRA (2005) says, the “lack of visibility” of the SE field.

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