Design principles for a didactic sequence on cell biology contextualized by social and ethical issues

Ayane de Souza Paiva, Ana Paula Miranda Guimarães, Nei de Freitas Nunes-Neto, Rosiléia Oliveira de Almeida

Universidade Federal da Bahia, Salvador, Bahia, Brazil

Abstract

The objective of this study is to analyze the features (design principles) of a didactic sequence on cell biology, specifically built to mobilize scientific contents, in different dimensions, with the purposes of developing argumentation skills on ethical issues as well as the performance of socio-political actions by high school students. Based in the assumptions of Science, Technology, Society, and Environment (STSE) Education, it is our concern in this work that ethics should be more carefully considered in science education, because it contributes to thinking and communication skills, such as critical thinking and logical reasoning. The research involves the adoption of Socio-Scientific Issues (SSI) that may increase the participation of students and promote their civic education. Guided by educational design research as a theoretical and methodological framework we built, to answer our research question, six design principles for planning a first prototype of a didactic sequence on cell biology that values the dialogic and critical teaching, with explicit openness to ethical discussions to reasoning about broader social elements. These design principles presented here were built through a collaborative work between three professors of higher education and a teacher of high school. It will be applied in a cell biology course, guided by these principles in the real context of classroom.

Keywords: cell biology teaching; socio-scientific issues; educational design research.

Corresponding author e-mail address: ayane.paiva@hotmail.com

Introduction

Cell biology is an abstract field in biology and many teachers report difficulties in teaching subjects related to it (REIS *et al*., 2013). A review of publications on cell biology teaching demonstrated the existence of an effort to diversify teaching approaches (PAIVA; GUIMARÃES; ALMEIDA, 2015). In spite of this, there is no evidence on the effectiveness of these strategies in learning. In addition, it is common in cell biology teaching, the adoption of a scientific perspective, normally exclusively focused on technical procedures and theoretical knowledge, associated with a lack of historical and ethical contextualization of the scientific content (PAIVA; GUIMARÃES; ALMEIDA, 2015). In opposition to this trend, Lima and Ghedin (2009) suggest that ethical contents should explicitly appear in science education because they contribute to the formation of citizens which are able to reflect on their own actions. It is our concern in this work that ethics should be more carefully considered in science education, because it contributes to thinking and communication skills, such as critical thinking and logical reasoning (BONJOUR; BAKER, 2007).

Accordingly, our work is aligned with the general field of Science, Technology, Society, and Environment (STSE) education. STSE education emerged in the 1960s and 1970s, as an alternative to the fragmented and technical scientific education, which also do not commonly discuss the social or environmental dimensions of scientific contents, nor involve the fostering of critical thinking (PÉREZ; LOZANO, 2013). It is important to notice that this more traditional, fragmented and technica scientific education is normally centered on the formation of scientists and technologists for the capitalist production system. In the social contextualization of science and in the analysis of the ethical and moral implications, it is relevant to use the Socio-Scientific Issues (SSI), which include discussions, controversies or issues of public interest, directly related to scientific and technological research of great impact on society. The science education focused on working with SSI foster the participation of students and promotes an open and critical education that contributes to their civic education (PÉREZ; LOZANO, 2013). Furthermore, the use of SSI refers to a markedly more developed teaching strategy as it aims to cultivate the moral education of students, thus providing the basis for a scientific education concerned with both cognitive and moral training of students (ZEIDLER *et al.*, 2005).

So, the SSI can be adequately seen as concrete tools for the operationalization of the STSE education. The discussion of SSI in the classroom requires a range of skills to analyze problems, as well as to work toward decision-making, such as: understanding of the meaning of implications, assumptions and inferences; understanding of the epistemological grounds of scientific knowledge; recognizing the influence of theory in the observation and vice versa; understanding of the relevance of science; distinction between issues that have a scientific basis and issues linked to other types of knowledge; recognition of values and perspectives that impact on the personal and social decision-making, involving science; evaluating evidence from different points of view (DRIVER; NEWTON; OSBORNE, 2000).

The SSI are typically controversial in real social situations in which they appear and thus must be organized, in the educational field, in the form of open-ended problems, subject to multiple points of view and solutions, having, beyond the conceptual links with scientific knowledge, clear relationship with moral considerations of individuals (SADLER; DONNELLY, 2006), which is strongly associated with the critical pedagogy of Paulo Freire (1987, 1992), one of the inspirations of our work in scientific education.

The political purpose was not always (explicitly) considered in science education, and some approaches to teaching science maintain a naive conception that, even by omission, supports an ideological model for maintaining the social and environmental *status quo* (SANTOS, 2008). For that, beyond the purpose of science education supported in critical pedagogy, which aims to prepare citizens for technological societies, it is necessary to have a clearer view of science education as having a sociopolitical purpose. Thus, to associate and apply critical pedagogy proposed by Freire to science education is to build a more radical view of science education from the perspective of an education that can change the unequal societies of the globalized world (SANTOS, 2008), as well as the situation of environmental degradation (KAHN, 2010). So, we propose a critical education that takes into account the mobilization of students for social responsibility, sociopolitical action, reinforcing the goal of development of attitudes and values involved in social and environmental issues.

And let it not be said that, if I am a biology teacher, I must not "go off into other considerations"– that I must *only* teach biology, as if the phenomenon of life could be understood apart from its social-historical, cultural and political framework. As if life, the very life, could be lived in the same way, in all of its dimensions, in a slum or 'cortiço' as in the prosperous area of São Paulo's 'Jardins'! If I am a biology teacher, obviously I must teach biology. But in doing so, I must not cut it off from the whole (FREIRE, 1992, p. 78, our translation).

Such consideration of Freire about the broader range of topics to be addressed in the biology classroom, is consistent with Zabala's (1998) understanding of the term *content*. This author mentions that the learning contents cannot be reduced solely to the contributions of disciplines or traditional subject matters. So, also are learning contents all those

elements that enable the development of motor skills, affective, interpersonal relationships and social insertion. Thus, based on this we broke with the strongly disciplinary and, in the words of Zabala, propaedeutic perspective of education; and, then we stand in support of an understanding and organization of teaching, assuming a broader conception of content. According to this conception we must recognize the conceptual, procedural and attitudinal dimensions of the different contents, carefully looking at their respective theoretical and philosophical grounds, while we are designing didactic sequences (CONRADO; NUNES-NETO, 2015).

From this perspective – based on this broader conception of content and on the assumption of SSI as consistent teaching strategies to address these contents - we propose to go beyond the mere reproduction of accumulated knowledge. We are moving, then, for an education that could form citizens able to act fairly in their social contexts, through sociopolitical actions (CONRADO; NUNES-NETO, 2015).

Thus, the objective of this study is to analyze, through a collaborative work, the features (design principles) of a didactic sequence on cell biology, specifically built to mobilize scientific contents (in different dimensions, as explained above), with the purposes of developing argumentation skills on ethical issues as well as the performance of sociopolitical actions by high school students.

The Design Research as a theoretical and methodological framework

The Educational Design Research, characterized by being a theoretical and methodological framework that has as purpose the systematic study of designing, developing and evaluating educational interventions as solutions to complex problems of the educational practice, guides, from a methodological viewpoint, this research (PLOMP, 2009). The aim is to develop educational innovations but also to increase knowledge of the planning and implementation processes in the classroom about the characteristics of interventions that are promising for the achievement of certain educational expectations. The expansion of knowledge and practices happens through discussion, construction and validation of the design principles, understood as theoretical products of the educational design research, that may compose a particular teaching theory for a given domain (for example, for cell biology teaching, focus of this work) (PLOMP, 2009).

One of the studies included in this type of research are the development of educational innovations (NIEVEEN *et al*., 2006). These studies aim to solve complex educational problems through systematic research that enables the construction and validation of the design principles of the educational innovations that can be applied in different contexts. These studies involve the iterative development of educational innovation by testing cycles of different versions or prototypes in different contexts, with increasing numbers of participants. In this iterative movement, the prototypes of educational innovation in development are tested and in each test cycle there is a partial result used to refine the next prototype. A specific teaching theory for a certain domain, the result of a development research, can be tested by another type of study included in educational design research, called the validation studies (NIEVEEN *et al.*, 2006).

Thus, according to Plomp (2009) development studies include 3 stages: (1) preliminary research; (2) prototyping phase; (3) evaluation phase. For the present study was made only the preliminary phase, in which design principles were built to guide a didactic sequence which aims appropriation (more than just understanding) by the students of the conceptual, procedural and attitudinal dimensions of contents about mitosis and cancer, from the discussion of a SSI and activities on argumentation in ethics, based on the history of Henrietta Lacks and the HeLa cells. This phase involves literature review and study of real teaching context for the proposition and production of a conceptual framework that will guide the study and the establishment of initial design principles for the construction of the intervention. The teacher knowledge and her classroom experience, for the research approach we adopt, have a main role in the construction of educational innovation at this stage. The phases 2 and 3 will be held in the future, because they are part of the first author's PhD dissertation, a work in progress.

In this work we built design principles that follow the wording proposed by Van den Akker (1999). These principles have the characteristics that guide the construction of educational innovation. Thus, to systematize these principles, Van den Akker (1999, p. 9) proposes the following formula:

If you want to design intervention X for the purpose/function Y in context Z, then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R (VAN DEN AKKER, 1999, p. 9).

This formulation by Van den Akker was adapted by the *GCPEC* research group, and the result is the following formula to spell out the design principles (see Sarmento, 2016, p. 23):

If you want to build an intervention X for the purpose/function Y in a context Z, it is advisable: (1) to adopt the feature A, for the purpose/function y1, performing the procedure K, in reason of the argument P. (2) Adopt the feature B, for the purpose/function y2, performing the procedure L, in reason of the argument Q. (3) Adopt the feature C, for the purpose/function y3, performing the procedure M, in reason of the

argument R (SARMENTO, 2016, p. 23, our translation).

It is important to note, in Van Den Akker's formulation, that the design principles can be "substantive", when referring to general characteristics of the intervention, or "procedural", when they are about features of an application of intervention in a specific classroom. Substantive principles constitute theoretical generalizations in the Educational Design Research. The procedural principles, in turn, vary according to each specific application.

Theoretical products of the educational design research, that is to say, specific educational theories to a certain domain, composed by substantive design principles, constitute generalizations that can be transferred to other educational contexts.

Within the teaching perspective and construction of educational innovations that we adopted as an assumption o our educational research, such innovations are better developed and investigated in collaboration, that is, in contexts involving both knowledge and practices of teacher-researchers of schools as well as of university researchers. This heterogeneity of subjects, knowledges and practices brings important contributions for the construction of pedagogical practice and educational research, providing theoretical, methodological and affective support for the construction of an innovative practice within the educational system. This research method is defended by many authors that emphasize the school as a producer of knowledge, and active participant in educational research (ZEICHNER, 1998; HARGREAVES, 1999; IBIAPINA, 2008).

Thus, this collaborative approach around the building and investigation of the educational practices aims to share knowledge and experiences among different subjects that have their own, specific, but extremely important, knowledges. In this way, the integration of tacit knowledge and theoretical and methodological knowledge of teacher-researchers and university professors seeks to build of the innovation and the development of educational research with rigor and legitimacy both from the perspective of the research, and as the practice, taking due account of the teaching knowledge and the classroom context.

Therefore, the design principles presented here were built collaboratively between three professors of higher education and a teacher of high school. In the future, there will be an application of the didactic sequence on cell biology, guided by these principles in the real context of her classroom.

A proposal with six Design Principles

It is relevant to notice that the didactic sequence was designed to create conditions for the appropriation of conceptual, procedural and attitudinal dimensions of the scientific contents (ZABALA, 1998, CONRADO; NUNES-NETO, 2015), as we have explained above.

Guided by the educational design research, as we have discussed above, in order to answer our research question we propose six design principles for planning a first prototype of a didactic sequence on cell biology that will be applied in the real context of the classroom. Thus, to plan our didactic sequence we characterized the intervention in terms of design principles described below.

(1) The use of popular science texts. This is intended to foster the understanding and appropriation of scientific knowledge in a systematic way, promoting debates in the classroom and contextualization of the history of science. It will happen from reading and discussion of popular science texts adapted to the teaching and research context in small groups of students. Here it will be used the book "The immortal life of Henrietta Lacks" that explains about the use without consent of the HeLa cells (SKLOOT, 2011). The use of popular science texts is an activity inspired by the literature has discussed its potential for teaching the concepts of school science in relation to the interests, experiences and knowledge of students (SARMENTO *et al.*, 2013; ZANOTELLO; ALMEIDA, 2013). In addition, an approach that involves history and nature of science (NoS) has been widely demonstrated as important for student training (MATTHEWS, 2015). In this sense, we discuss the nature of science in its historical and social aspects, from the contextualization and systematization of the process of building scientific knowledge on mitosis and cancer, based on the case of Henrietta Lacks.

(2) Approach based on arguments in biology education, to develop the student's capability to argue and defend ideas in an organized, structured and qualified way, from a Simulated Jury which will be held in the form of guided discussion on ethical dilemmas about the use of HeLa cells. This is a basis for the learning of argumentative skills, that consider didactically the following steps: 1) Identification of the arguments, including premises and conclusion, using the indicators for the two components of the argument; 2) identification of fallacies, with an analysis of the validity of the arguments, and finally 3) Creating arguments with at least two premises and one conclusion. The class will be divided into two major groups and will be drawn two defense situations: 1) use of human tissue in research without consent and 2) use of human tissue in research only with consent. It will be necessary to adapt this strategy to the reality experienced by the collaborator

of high school as she realizes the conflicts among students when they are faced with situations involving explicit judgments. The Simulated Jury will mainly be used to promote arguments activity considered essential in social processes related to communication and learning science (DRIVER; NEWTON; OSBORNE, 2000; LIMA-TAVARES; MORTIMER; EL-HANI, 2009). Moreover, this principle seeks to promote autonomy of study and cooperation throughout the debate and encourages critical thinking about the ethical dimension of the use of human tissue in scientific research.

(3) Didactic use of real SSI. This is the case because we focus on appropriation and critical discussion of conceptual content, including relevant ethical concepts, and analysis of specific situations involving *othering processes* of race, gender and class oppression in the history of science. The students will analyze, in small groups, real SSI, involving cell biology concepts, ethical dilemmas and othering processes of race, gender and class oppression. We adapt the use of SSI indicated by Hodson (2011), from the use of a simpler SSI - more structured in its questions - and a more elaborate - less structured, in order to adapt to the context of the school and the educational reality that is not practiced with questions, but, in general, with classes poorly associated to problem solving. The reason for this principle is to enable students to consider how science-based issues and decisions concerning them reflect, partly, moral principles and qualities of virtue that include their own lives and the social world around them (ZEIDLER *et al*., 2005). To understand the concept of othering processes, and how they can lead to exclusion and social marginalization (which in ethics, is properly indicated by the notion of exclusion of moral consideration, or exclusion of the circle of moral consideration) we need to understand that they are mediated by speeches or techno-scientific practices both in history and in contemporary times (ARTEAGA; EL-HANI, 2011). Moreover, the discussion of the relationships between oppressor and oppressed – already referenced by Paulo Freire (1987, 1992) - is potentially useful to generate critical thinking and social engagement. Furthermore, several reports have provided empirical evidence of the prominence of moral considerations in the negotiation and resolution of SSI (SADLER, DONNELLY, 2006). These same studies suggest that moral considerations influence how individuals negotiate a variety of SSI, including biomedical investigation (PÉREZ; LOZANO, 2013).

(4) A teaching based on dialogic and critical perspective of Paulo Freire, focused on the development of critical and dialogic skills, as well as on sociopolitical engagement by students. Educational activities that promote the active participation of students at all times of the classes, from three methodological aspects of Freire's view: discussion of socially relevant topics through the use of SSI, establishment of a dialogical process in the classroom and engagement of students in sociopolitical actions. The importance of establishing dialogical and interactive communicative approaches in the classroom has been already pointed out in science education from the psychological and socio-historical points of view (MORTIMER; SCOTT, 2002). In this process, educators face the challenge of the duty to depart from the discourse and practices of a *supposedly neutral* political stance, at the same the time they should not impose on students their own specific values. Thus, a moral and political education should involve, above all, appropriation - by students – of knowledge and critical reflection on the different values, supported by different social actors involved in the SSI under analysis. Only from such appropriation and reflection, based on science, but also, fundamentally, in ethics, students can understand more clearly their own evaluative positioning, judging it critically, and, at the same time, note that there are other possible positions on the subject; this allows them to make better choices (SANTOS, 2008).

(5) Cooperative work, aiming to provide students to work together in the search for an agreement on the process and a common result, through discussion on the contents, both in the construction of shared knowledge to be discussed as mobilizing attitudinal contents, such as respect and tolerance, from different types of group activities. This principle is important, because it has been described in the literature that the students, working cooperatively, discussing ideas and situations, better structure their own learning (FERNANDES, 1997). Besides that, little opportunity has been given by teachers for discussions by the students themselves, while in groups, on the interpretation of events, experiences, or social issues, although participatory methods are important to engage students in thinking processes and discussion in class (DRIVER; NEWTON; OSBORNE, 2000).

(6) Explicit teaching of ethics, in order to stimulate thinking about the different value judgments on issues involving STSE and the possibility of making rational ethical-moral decision-making involving everyday situations. This, we propose, should be based in some explanation of the main currents in moral philosophy - the deontological ethics, the consequentialist ethics (including pragmatic ethics and utilitarian ethics) and the virtue ethics (BONJOUR; BAKER, 2007) - and discussions on the actuation one or more these theoretical perspectives in decision making and its social implications. We consider this principle promising, since there is a gap of discussions on ethical issues in science classrooms (BRYCE; GRAY 2004). Moreover, Lima and Ghedin (2009) suggest that ethical contents should be taught explicitly in science education, because ethics contributes to the formation of responsible citizens, which are more reflective about the moral meaning of their own actions. The same point is defended by Pedretti and Nazir (2011),

who argue about the relevance of an education that includes an informed decision making, ability to analyze, synthesize and evaluate information from the ethics and moral reasoning. Thus, the school has a fundamental role to present ethical and moral dilemmas present in the exercise of scientific activity throughout history, encouraging exercise and the process of sociopolitical decision-making, on complex aspects of contemporaneity (JENNINGS *et al.*, 1991).

In this way from the Freirean critical pedagogy, focusing on the political purpose of transforming oppressive conditions in society, through a radical view of scientific literacy, we recommend the use of SSI and the establishment of a dialogical process in the classroom, and the creation of conditions for development, in the long run, of the sociopolitical actions (SANTOS, 2008). In sum, with these different principles (which are closely linked to each other), we hope to build a didactic sequence able to allow the appropriation by the students of the conceptual, procedural and attitudinal dimensions of scientific contents. This, we expect, will contribute to a more integral scientific education on cell biology.

Final Remarks

Because of the problem linked to the prevalence of uncritical and scientific educational approaches, excessively focused on concepts, in the cell biology, we advanced in this investigation features for an innovative didactic sequence. From a theoretical framework it takes in due account the teaching dialogic and critical aspects, with explicit openness to ethical discussions on broader social elements. Here we have proposed six design principles for a critical and integral cell biology teaching; and in the future works, we will present results of the evaluation of the didactic sequence.

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