STRUCTURING STUDENTS' CRITICAL DISCUSSIONS THROUGH PROCESSES OF DECISION-MAKING ON SOCIO-SCIENTIFIC CONTROVERSIES

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ABSTRACT: Teachers or educational designers who prepare teaching activities in which groups of students have to discuss and decide upon controversial socio-scientific issues are faced with a fundamental dilemma: on the one hand the discussions are at risk to have no real connection to any science content; on the other hand, if the terms of the activity are too bound by the teacher, the purpose of creating a forum of real student autonomy is lost. This paper lays the theoretical groundwork for how educational designers could avoid this dilemma. A theoretical exposition of the concepts of 'controversy', 'discussion/argumentation', and 'decision-making' reveals that it is possible to understand the students' discussions towards decision-making on controversial socio-scientific issues as processes of resolution and modelling. This understanding, in turn, allows the application of an educational design approach for modelling activities that is well-known in mathematics education.

KEY WORDS: Socio-scientific controversies. Decision-making. Argumentation. Critical discussions. Educational design.

A ESTRUTURAÇÃO DE DISCUSSÕES CRÍTICAS DOS ALUNOS ATRAVÉS DE PROCESSOS DE TOMADA DE DECISÃO SOBRE CONTROVÉRSIAS SÓCIO-CIENTÍFICAS

RESUMO: Os professores ou educadores que preparam actividades de ensino nas quais grupos de alunos têm de discutir e decidir sobre controvérsias sócio-científicas são confrontados com um dilema fundamental: por um lado as discussões correm o risco de não ter ligação real com qualquer conteúdo de ciência; por outro lado, se as condições da actividade são demasiado controladas pelo professor, o objectivo de criar um fórum

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de autonomia real para os alunos fica comprometido. Este artigo estabelece os fundamentos teóricos para os educadores evitarem este dilema. A exposição teórica dos conceitos de "controvérsia", "discussão/argumentação" e "tomada de decisão" revela que é possível entender as discussões dos alunos para a tomada de decisões sobre controvérsias sócio-científicas como processos de resolução e modelação. Por sua vez, este entendimento permite a aplicação de uma abordagem de concepção de actividades de modelação que é bem conhecida em educação matemática.

PALAVRAS-CHAVES: Controvérsias sócio-científicas. Tomada de decisão. Argumentação. Discussões críticas. Design educacional.

INTRODUCTION

Background

For nearly two decades the science education community has given increased attention to student argumentation (DRIVER; NEWTON; OSBORNE, 2000; JIMÉNEZ-ALEIXANDRE; ERDURAN, 2008), socio-scientific decision-making (RATCLIFFE, 1997; KORTLAND, 2001), and (for even longer) socio-scientific controversies[1] (STENHOUSE, 1971; HERMANN, 2008; LEVINSON, 2006). This attention is echoed in many national curricula: in the Danish school system, for example, fostering students' argumentative and socio-scientific decision-making competencies is explicitly mentioned as an aim in the curriculum of the science disciplines and mathematics on both the lower and upper secondary level (DANISH MINISTRY OF EDUCATION, 2003; 2008). Besides the pedagogical reasons of aiding to the development of higher cognitive and epistemic capacities the prime reason for focussing on argumentation is one of being sensitive about how teachers represent the human endeavour of science to students (see e.g. JIMÉNEZ-ALEIXANDRE; ERDURAN, 2008). It is proposed that argumentation for, and discussion of socio-scientific statements should have a central role in science teaching, because it echoes the image of science as an endeavour of negotiating and constructing knowledge which is painted by many philosophers of science and science studies scholars. As Latour and Woolgar argued on the basis of their seminal studies

[1] In this paper, the term 'controversy' is part of the study object. I therefore ask the reader to indulge me in this introduction and accept my usage of the term as a placeholder before a thorough definition is discussed in the next section. The term has had different usages at different times and, in particular, in different geographical regions. In the United States the paradigm example in the literature seems to be the case of evolution (HERMANN, 2008); while in Britain and the European continent the term *also* covers more narrow or local issues from everyday life interactions between science and society. (LEVINSON, 2006; REIS; GALVÃO, 2004)

of the microsocial phenomena of laboratory work, "a scientist's activity is directed, not toward "reality," but toward [...] operations on statements" (LATOUR; WOOLGAR, 1986, p. 237). In this image of scientific activity the primary modus operandi of the scientist is argumentative in nature.

It should be clear that one of the primary aims of emphasising argumentation and discussion in the science classroom is that of enabling students to be reflective and critical about controversial issues *in* science, and more importantly for our purpose, about the controversies pertaining to the *interaction* between science and society – i.e. topics related to the advancements of science (stem cell research, germ line gene therapy, genetically modified organisms, etc.) as well as how scientists advice citizens (the BSE incidents in Britain in the 80's, hazardous effects of commercial products, how to act in face of global climate changes, etc.).

Recently, there have been some indications of a shift in focus from students' reasoning – i.e. constructions of singular argumentative moves – to the more dialogic articulation of moves within critical discussions – i.e. the process of producing argumentative moves in discussion contexts (KUHN; UDELL, 2003; CLARK; SAMPSON, 2008). To my mind, such a shift is very welcome; but it also presents us with a challenge: Though some considerations have been made on how to *design* educational activities that scaffold or support student argumentation (JIMÉNEZ-ALEIXANDRE, 2008), and though there has been done some work on interaction design to stimulate computer mediated discussions (RAVENSCROFT; MCALISTER, 2006), we need to consider in very fundamental terms what it means to take a didactical design approach to argumentative *discussion* activities in which students make decisions on socio-scientific controversial issues.

PURPOSE AND OUTLINE OF THE ARGUMENT

A fundamental dilemma, which faces teachers and other actors who design activities in which students are to discuss and decide upon a problem issue, is that of finding a safe passage between the *Scylla of no student autonomy* (i.e. activities with a fully pre-deûned structure, where the students do not experience making their own path towards a decision which has not been autonomously agreed upon), and the *Charybdis of radical student autonomy* (i.e. activities with no necessary anchoring in the disciplines, and with no disciplinary content being used to organize the problem issue). In particular, merely asking students to discuss socio-scientific issues, does not necessarily secure that the students' discussion latches on to, or is anchored in, a scientific disciplinary content. (RATCLIFFE, 1997)

The purpose of this paper is to point to how educational designers and science

teachers can alleviate themselves from the problems posed by this dilemma. The basic claim that is put forward here is that some solace can be found at the level of theoretical analysis in the design process. This claim is substantiated through an *a priori* groundwork for designing learning activities that engage students in a critical discussion process with the explicit aim of making a group decision about a controversial socio-scientific issue. The paper, thus, should be considered to be a prolegomena for a future *terminology*, which we might use when designing for critical discussion and socio-scientific decision-making.

By these lights, the aim of this paper is not the ambitious one of providing a more or less concrete design approach for specific subjects or problem issues. My intention is, rather, to theoretically vindicate that a sensible choice of a controversial issue within a specific design approach from mathematics education research known as "study & research courses" (SRC), which belongs to the *anthropological theory of didactics* (ATD) (CHEVALLARD, 1992b; 2006), in principle could be applied on decision-making activities that centre on critical discussions.

Let me briefly sketch the main argument of the paper. After portraying the dialectics of how we should understand exactly what a controversial issue is, I will propose a notion of controversy as revolving around an argumentative resolution process. I then introduce the main principles and motifs behind the SRC approach to modelling activities. I then argue that the theoretical notion of decision-making processes allows us to understand such processes as modelling processes, and thus that they are activities which we can design using SRC. Finally, I argue that *if* we abandon an understanding of critical discussions as a series of individual argumentative moves, and, rather, adopt an understanding of such discussions as being dialectical processes that are teleologically guided by a principle of resolving a difference of opinion, *then* we have available an understanding of the relevant discursive trajectories in discussions as being both drawn and directed by the motive of deciding upon a controversial issue in a fashion similar to the learning trajectories in the SRC approach.

THE HISTORIC CONTROVERSY ABOUT THE 'CONTROVERSIAL' AND THE CURRICULUM

Basic observations

I want to restrict my focus on the nature and role of controversy in the discipline of science *education*. I will not directly concern myself with the nature and role of controversies in science, and, consequently, I will not address actual controversies

about scientific claims within the scientific community. I want to, rather, specifically address the way controversies can serve educational purposes. A prudent way to launch such a discussion is to take outset in a relatively high level of abstraction and briefly consider exactly what we could mean by the term 'controversy', or, more precisely, what do we mean when we say that there is something about which there is a controversy. Interestingly, the meaning of controversy is a somewhat debateable issue it self. Indeed, often insufficiently defined, the term 'controversy' was the subject of an academic discussion during the 1970's and 1980's. The immediate concern of that discussion was how educational scholars best parse the notion of controversial issues vis-à-vis the justification for the idea that such issues should play a role in curricula. In the following I intend to briefly delineate the dialectics of that discussion and in parallel label five distinct conceptions of controversy and of its role in science education.

Let me make some very general notes about the controversial that apply to historic and current controversies in academia and society (the issues that we want to introduce students to) as well as the controversies in the classroom (the issues that the students are to actively participate in discussing). It seems clear that the concept of a controversy involves three aspects. First, there must be some sort of identifiable *issue* – i.e. something that the controversy *is about* – and we should reserve the term 'controversial issue' for such issues. Second, we should expect there to be some persons *for whom* that issue is controversial (otherwise it would only be a potential controversy). Third, we are dealing with some sense of *disagreement* between the parties involved, and this disagreement will be manifested in the standpoints taken by the parties and the parties' assertions about the issue. The historic discussion of how to understand the controversial in an educational context is, as we shall see, basically a question of which auxiliary aspects beyond the three above we should expect to characterize the controversial.

THREE CONCEPTIONS OF CONTROVERSY

The dialectics of the discussion about the controversial originally came to a head with the reports from *The Humanities Curriculum Project* a project under the Nuffield Foundation organised by Lawrence Stenhouse. The primary aim of that project was to investigate "the problems of teaching in controversial areas" (STENHOUSE, 1971, p. 155) where, a controversial issue was defined as "one which divides students, parents and teachers because it involves an element of value-judgement which prevents the issue's being settled by evidence and experiment" (SCHOOLS COUNCIL/NUFFIELD FOUNDATION, 1970, p. 6, apud

GARDNER, 1984, p.385). I shall refer to this rendition as the *evaluative* definition of the controversial. And the core of this definition is that the type of disagreement at play in controversies is always a disagreement in terms of the values of the parties involved. As we shall see, it is this rendition, to which other scholars have reacted.

Let me make an observation on the *evaluative* definition. On the face of it the *evaluative* definition appears to be intuitive and innocuous. This is so, in particular, when we consider the general educational philosophy proposed by the project: "to develop an understanding of human acts, of social situations and the problem of value which arise from them" (STENHOUSE, 1971, p. 155) and to put an emphasis on "[t]he fundamental educational values of rationality, imagination, sensitivity, readiness to listen to the views of others" (p. 156). The justification of introducing controversial issues in classroom teaching, then, is to communicate to students the culture- and value-laden way of dealing with issues that affect society – issues which, it is held, cannot be analysed without remainder by scientific evidence or experimental procedures. As such, this educational philosophy is very similar to the traditional "Socio-Scientific Issues" (SSI) movement within science education (see e.g. RATCLIFFE, 1997; SADLER; CHAMBERS; ZEIDLER, 2004) which can be best characterized as activities in which students negotiate and decide upon problem issues that have a ideological/ethical nature and are conceptually related to some more or less specific science content. There is a notable difference though: the SSI movement also focuses explicitly on subject matter content, and such a focus is not as explicit in the Humanities Curriculum Project. What is apparent is that the *evaluative* definition of the controversial is borne out of the aims and underlying educational philosophy of the Humanities Curriculum Project. But does the definition adequately describe what a controversial issue amounts to?

Charles Bailey (1975, p. 122) took issue with the *evaluative* definition by stressing that:

> Controversies can occur in any area of knowledge or experience. There can be controversy about scientific matters, aesthetic matters, historical matters, controversies about religion and cosmology as well as about morals, society and politics.

Bailey was concerned to make explicit that there are also controversies that do *not* primarily involve value-judgements – i.e. disagreement in terms of values involved cannot be a necessary condition for the controversial. To emphasise this point Bailey lowered the criteria: the fact alone that there is a disagreement constitutes that we are dealing with a controversy, and this fact, he said, is a

"*social* fact", and he elaborated that "an issue is controversial if numbers of people are observed to disagree about statements and assertions made in connection with the issue" (p. 122, my italics). Such would be a *behaviouristic*[2] conception of controversy in which the necessary condition for an issue to be controversial rest on whether or not there exist persons that disagree on it.

The behaviouristic conception of controversial issues received criticism. Robert Dearden argued that relying on such a "behaviouristic criterion" for what counts as a controversial issue leads to watering out the notion of controversy to such the extent that (even rudimentary) quarrels that result form "simple ignorance or [...] mere undisciplined assertiveness" should count as controversies disregarding that there could be "a clear decision-procedure and [...] a publicly known and available answer" to the issue at hand (DEARDEN, 1981, p. 38). The point that Dearden thereby raises is that we could very well – and often we indeed do – have instances of people disagreeing on something to which a definite answer is already known. And we must, I think, concede with Dearden that Bailey's attempt effectively reduces controversy to disagreement, and though all controversies certainly revolve around disagreements it is intuitive to think that not all disagreements are controversies. While I and another soccer aficionado could be involved in a debate about when the Danish national team last beat Brazil the issue itself scarcely deserve to be called a controversy, since official annals would have recorded the answer. By identifying something as a controversial issue, we surely want to do something more than simply point out that there are two or more parties that assert incompatible claims about that issue. And this point leads us to Dearden's second argument against the behaviouristic account: if we can call something a controversial issue merely because we observe that two or more parties assert mutually incompatible claims about that issue, we would disregard the argumentative groundedness of the asserted claims, and this, he argues, would propel us into an "epidemic relativism" (*ibid*). Though I concur with Peter Gardner's later conviction that this second argument of Dearden's is "difficult to follow" (GARDNER, 1984, p. 379), the point that Dearden wants to make is undoubtedly that if we want to find a place for controversies in the curriculum they should involve more than simply exchanges of disagreeing assertions, namely, the pro- and contra assertions that are involved should be endowed with some minimal epistemic authority in the sense that the assertions are being argued for by the respective parties. And this point is, of course, not negligible: by introducing a (*socio-)scientific* controversy

[2] I follow Dearden (1981) who labels the requisite criteria in Bailey's account "a behavioural crieterion" (p. 38).

into the science curriculum we should aim for more than simply point out to our students *that* persons disagree on this or that issue, our aim is, rather, that our students become aware that there possibly is a *scholarly discussion* which rests on *arguments* about the issue in question.

Such considerations lead Dearden to propose an alternative criterion for what counts as controversial issues. He himself labels that criterion the "*epistemic* criterion of the controversial" (DEARDEN, 1981, p. 38), and I will subsequently refer to the resulting conception of controversy as the *epistemic* conception. The epistemic conception of controversy differs from its behaviouristic counterpart by relying on epistemological facts rather than social facts: an issue is controversial "if contrary views can be held on it without those views being contrary to reason" (p. 38). Thus an issue is controversial, on this view, so long as two or more parties make assertions that, on the one hand, are in conflict yet, on the other hand, individually can be argued for in a sufficient manner within the confines of "the body of public knowledge, criteria of truth, critical standards and verification procedures which at any given time has been so far developed" (*ibid*).

CONTROVERSIES AS RESOLUTION PROCESSES

To be sure, the epistemic criterion is a very sensible criterion to expect when talking about what is and what is not a controversy. Nevertheless it seems that the epistemic conception of the controversial leaves some points about the practice of disagreeing wanting. This issue was initially raised by Gardner (1984). He notes that it would be a contradiction if an issue was:

> […] controversial but no one thought it to be of any importance and a purely epistemic account will not guarantee the satisfaction of the social condition of an issue being regarded as important. (p. 381).

In Gardner's view, the insistence on the social fact of a *real disagreement* – something which matters to the parties involves – found in the behaviouristic conception cannot be neglected and the epistemic account simply has no room for this criterion. It seems, further, that the epistemic account, at least as Dearden proposes it, is inconsistent with how people that are involved in controversies experience such a disagreement. Gardner provides an example:

> The person who judges and is firmly convinced that this country should not practise capital punishment and who admits that the question of capital punishment is controversial need not be seen as conceding that the appropriate criteria, critical standards and verification procedures

> […] are just as much on his opponents' side as they are on his; rather we may see the person accepting that he has the appropriate criteria, standards and procedures on his side and his opponents do not. (GARDNER, 1984, p. 382)

Gardner touches upon a salient point: It would be strange to suspect that if two parties were involved in a controversy that either party at some point accepts that the other party's argumentation is just as solid as that of her own – as if she would shrug and say that the claim contrary to hers is just as epistemically authoritative as hers. The danger, according to Gardner, is to end up communicating some sort of "subjectivism" in the classroom (p. 382). But my foremost concern here is to establish a suitable understanding of controversy that takes in to account the practices of being involved in a debate about a controversial issue. Gardner is hesitant to propose an alternative account, but I think we can extrapolate a central insight from what such an alternative could be on his view: Pupils, he says, "need to realize that people take stands and commit themselves for grounds and reasons and because they believe that they have the best case" (p. 384). What lies behind a controversy, on this account, is that people sometimes have (possibly minute) differences in worldview and that the schemas through which we understand the world to some extend determine the commitments and claims we make about the world. And what is important for the purpose of this paper is that controversies involve taking "a stand and commit oneself […] to believe one's opponents are wrong" (p. 384). The key point is that being involved in a controversy is analogous to play a game in which one argues for one's case and brings in to question the argumentation of the other. And though Gardner is reluctant to put forward an independent account of the controversial, I would like to point out that an account along these lines is already available.

Johnson and Johnson have since the late 70's studied different tropes of classroom conflicts. In their view, while a *debate* involves a situation in which "two or more students argue positions that are incompatible and a winner is declared on the basis of who presented their position best", a "[*c*]*ontroversy* exists when one person's ideas, information, conclusions, theories or opinions are incompatible with those of another person, the two seek to reach an agreement" (JOHNSON; JOHNSON, 1985, p. 238-239). I would like to call this account the *resolution process* conception. The first thing to note is that being in a process of trying to reach an agreement does not mean that the discussion is not heated or is not of importance for the parties involved. For although this account seems to imply that one must compromise in a discussion of a controversial issue, it is important to be aware that whenever we are engaged in a discussion we are in

some sense always already engaged in trying to 'win' the agreement of the other. Indeed, when one takes a stand against the argumentation of a person with a different standpoint on an issue, one implicitly (or explicitly) tries to get the other to agree. In other words, the reason that a controversy is often so heated and of importance to the parties involved is precisely because the parties attempt to reach an agreement. Interestingly, the resolution process account of controversy also involves an outlook on the facilitation of a learning process. Broadly put, a controversy is a subtype of a conflict, Johnson and Johnson argue, which "resides in the [parties'] attempt to resolve their disagreement", and this is related to the "*conceptual conflict*, which exists when two incompatible ideas exist simultaneously within a student's mind and must be reconciled" (JOHNSON; JOHNSON, 1979, p. 53). And it is this conceptual incompatibility that sparks a learning process – i.e. in light of the incompatibility the student must begin to recategorize and reorganizing information. In that sense, Johnson and Johnson discharges 'controversy' from its negative connotations and form a concept of "*constructive controversy*". (JOHNSON; JOHNSON; SMITH, 2000, p. 30)

We must be mindful, of course, that we do not mix incommensurable ontological categorise. There are notable differences between talking about controversies as conflicts in a persons mind, between two students in the classroom, between two citizens, or between two scientists, respectively. Nevertheless, we can, I think, develop an understanding of the essential character of controversies in all these different instantiations, namely as a resolution process. It is this account of the controversial, which I would suggest, and, as will be clear, it fits structurally with a well-established theory of argumentation that is useful when we want to understand group discussions on controversial issues. With the resolution process account of the controversial we can articulate an understanding of the controversial as something that involves two or more parties that have different standpoints, are able and willing to put forward argumentation for their own standpoints while scrutinizing the argumentation of the other in a process of resolving this difference of opinion.

This account of the controversial offers us a vocabulary to reformulate the primary dilemma with which we are concerned (the *Scylla of no student autonomy* and the *Charbydis of radical student autonomy*). The challenge that faces activities in which students discuss controversial socio-scientific issues becomes that of structuring the activity in a fashion such that students pass through the resolution processes autonomously in the sense that they are able to approach the issue from their vantage point, with their arguments, and reach a group decision on their own, but that the resolution processes the same time is well-structured in the

sense that the activity at least on a conceptual level connects appropriately to the relevant science content. I turn now to outline how educational design consideration from mathematics education can shed light on how to structure such processes.

ATD AND DESIGNING TRAJECTORIES

Fundamental assumptions of ATD

At the heart of the *anthropological theory of didactics* (ATD) we find the notion of *praxeology* – i.e. the notion that we "can analyse any human doing into two main, interrelated components: *praxis*, i.e. the practical part, on the one hand, and *logos*, on the other hand" (CHEVALLARD, 2006, p. 23). From the perspective of ATD, every human activity, such as conducting experiments in the lab, proving a theorem, or even riding a bike, is an actualisation of a praxeology. In this sense, a praxeology is to be understood as a generalisation of what we are used to call something like epistemic capacities – i.e. content knowledge, skills, and methods for acquiring new knowledge. Taking his lead from this outlook of the ecology of knowledge, Chevallard argues that praxeologies are *intersubjectively shared* by, and *idiosyncratic* to, groupings such as social classes, local communities, school classes and research communities etc. (CHEVALLARD, 1992a; TIBERGHIEN, 2008). For Chevallard, this means, on the one hand, that such groupings *construct* the group-specific knowledge and epistemic capacities they share, and, on the other hand, that any communication or transference of praxeologies from one group to another in the first instance requires that the given body of knowledge is *transposed* (CHEVALLARD, 1985; BOSCH; CHEVALLARD; GASCÓN, 2005). In the context of science and mathematics education this has the immediate consequence that any particular body of knowledge, which is produced through an actualisation of a particular praxeology, by the scientific or mathematics community must undergo a *didactic transposition* by the teacher and the institutional surroundings (e.g. the curriculum) so as to be taught in class. To be sure, this is a common theme in attempts to spell out exactly what the basic phenomena of education or didactics is; something very similar to this idea is found behind Klafki's considerations on "didactic analysis" for lesson planning (KLAFKI, 2000), and the concept of "educational reconstruction" proposed by Kattmann, Duit, Gropengieber and Komorek (1996).

The *sine qua non* of a praxeology is its function of solving problems: we invoke a specific praxeology to solve specific problems, like when John thinks to himself 'how am I to transport myself to campus today' is a problem, which John could

solve by riding his bike, thereby actualizing the praxeology familiar to him of riding a bike; similarly with the problem of establishing which commercial soap is the better soap. In general: when facing a problem, humans apply specific *techniques* to circumvent it; and praxeology is a useful way of parsing this conduct, because it is not merely a praxis, but a rational conduct in the sense that it, upon inquiry, can be drawn into question and justified. (CHEVALLARD, 2006). On this view, the key phenomenon in education is that students are introduced to new and more demanding praxeologies by being posed problems *specifically designed* for the educational context.

In this light, the primary task of educational design becomes one of transposing relevant bodies of knowledge in such a way as to afford meaningful and sensible *trajectories* of situations in which the students can acquire increasingly more complex praxeologies. And in the case of activities involving critical discussions about controversial socio-scientific parts of the relevant bodies of knowledge that need to be transposed would be the knowledge and practices of the scientific communities as well as the available knowledge and practices of societal debates involving a connection to science content. (TIBERGHIEN, 2008)

STUDY AND RESEARCH COURSES

It may be possible to argue that a fundamental challenge faces any attempt to describe the phenomena of educational situation in terms of concepts such as transposition or reconstruction. If bodies of knowledge and relevant practices are being *represented to* students how will these students acquire the defining traits of critical citizenry? This is, I think, a variation of the well-known "paradox of indoctrination" (MACMILLAN, 1983) – that teaching autonomous thinking seems to be paradoxically dependent on indoctrination in the process. And, in practice, it would typically manifest itself as what I have called the *Scylla of no student autonomy*. In the context of the theme of this paper the problem can be restated as one of securing that activities of critical discussions not just mean that students re-apply established knowledge and values that have been transposed to them, but negotiate and independently construct personal criteria for making the sought for decision. Chevallard, of course, is quite aware of such problems, and gives an elaborate account of how ATD facilitates activities in which students are "finding things *out*" instead of merely finding things by visiting the "monuments" into which the didactic transposition has turned bodies of knowledge. (CHEVALLARD, 2006, p. 29)

To this end Chevallard envisages a generic type of teaching situations which he

labels "study & research course" (SRC) – where 'research' is meant to explicate the modus of student participation, and where 'course' is in the sense similar to that of a golf course – a course which is "determined essentially by the will to bring an answer, *A*, to some *generating question*, *Q*" (CHEVALLARD, 2006, p. 28). For Chevallard this course is akin to an "institutional *adventure*" (*ibid*); and the didactical design approach in SRC is accordingly to articulate a generating question for a given subject area and foresee, through *a priori* analysis, a "theoretical trajectory" (WINSLØW, 2009) of this adventure.

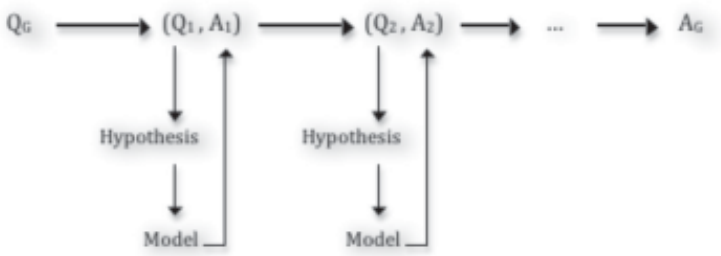

Fig. 1 – The structural dynamics of a SRC modelling activity. Notice how the generative question Q_G as it were 'spans' out a trajectory through a particular body of knowledge by generating sub-questions (Q_1, Q_2, …). These questions, in turn, motivates the construction of models in order to receive corresponding answers (A_1, A_2, …). It is through following this trajectory that students eventually are able to answer the generating question (with A_G). Adapted after Barquero (2008).

Baquero, Bosch and Gascón (2007) offer a detailed explication of the nature and purpose of SRC in terms of conceptualising how to structure the trajectories of invoked and articulated praxeologies in mathematical modelling activities: The central idea of SRC is that we are dealing with an activity that involves:

> […] the study of a question *Q*, of real interest to the students ("alive"), and strong enough to generate many other questions. The study of *Q* and the subsequent questions it generates lead to the construction of a large body of knowledge […] The sequence (or "tree") of questions generated by an initial question *Q* is, in fact, a sequence of pairs questions/answers: (Q_i,R_i). The [SRC] thus permit retrieving the original relationship between questions and answers, or between problems and theories. This relationship is a key for the construction of scientific knowledge in general and for the activity of mathematical modelling in particular. (BARQUERO; BOSCH; GASCÓN; 2007, p. 2052)

In this way, the study & research programme allows students to research a given problem that, on the one hand, generates a series of increasingly more

difficult and complex sub-problems, and on the other hand, itself can only be comprehensively solved through the interaction with its sub-problems – i.e. the process of solving the generative problem is scaffolded by the sub-problems it itself generates. And, though the main task of the didactic transposition consists in making the relevant body of knowledge explicit as being that which answers a series of questions, the fundamental aim of this approach is that it affords a type of activity in which the modelling activity itself becomes the "study object" (BARQUERO; BOSCH; GASCÓN, 2007, p. 2059) and thus that the students are not re-applying established knowledge that has been transposed to them, but negotiate and independently construct models. Notice the normative indication in the quote above: not any question can serve the purpose of being a generative question. To my mind, we can, based on this, give a gloss on this in the following way: appropriate generative questions have the feature of being *rich* and *forceful* – rich in the sense of entailing *a priori* a series of sub-questions/answers that call for increasingly complex models, and forceful in the sense of being able to really guide the students through the trajectory of that series of situational models.

To summarise, the primary insight that we draw from ATD/SRC in this context is the idea that the appropriateness of the design of an educational modelling activity depends on the appropriateness of the chosen generative question in terms of how well that question is able to generate a series of sub-questions/answers and thus *teleologically* guide students through a foreseen modelling trajectory. And it is this insight and its individual constituents that I will try to superimpose onto a theoretical model of critical discussions and decision-making processes in the following.

CRITICAL CITIZENSHIP AND DECISION-MAKING PROCESSES

Background and precision of focus

In the last decade there have been strong calls for future citizens to be more *scientifically literate*. Two generic *raison d'être* for this call are typically cited: one stemming from extrinsic socio-economical grounds (EUROPEAN COMMISSION, 2004; ROCARD et al., 2007), and one stemming from socio-cultural grounds (OSBORNE; DILLON, 2008). It is arguably the case that activities in which students engage controversial socio-scientific issues has a place and role in science teaching regardless of whether one's reasons for promoting scientific literacy come from wanting to secure that enough people chose a science career in the future or whether one's reasons come from wanting to secure scientific understanding (and

understanding of science) as an important aspect of our cultural heritage. For the tendency is to stress the *societal* and *critical* dimensions of scientific literacy seen as epistemic capacities to "help make decisions about the natural world and the changes made to it through human activity" (OECD, 2003). The term 'critical' is meant to emphasize that only if citizens are put into position to respond to complex societal issues in a *responsible*, *rational* and *reflective* manner can societies tackle the increasing number of collective risks (BECK, 1992) and novel challenges (GIDDENS, 1990) with which they are faced. And since scientific content is woven into the fabric of the complex societal issues of the 21st century, teaching for scientific literacy becomes key in the formation of critical citizens. It is increasingly clear that we have to regard teaching for scientific literacy as involving the preparation of students for a kind of citizenship, which can be characterised as broadly critical. (see e.g. AIKENHEAD, 2005; KOLSTØ, 2001)

At this point it would be useful to emphasise a distinction from media theory between two very distinct processes that are at play when two or more individuals communicate. While processes of *conveyance* denote the processes involved with "the transmission of a diversity of new information [...] to enable the receiver to *create* and *revise* a mental model of the situation", processes of *convergence* denote the processes involved with "the discussion of preprocessed information about each individual's *interpretation* of a situation" where the "objective is to agree on the meaning of the information, which requires individuals to reach a common understanding *and* to mutually agree that they have this understanding" (DENNIS; FULLER; VALACICH, 2008, p. 580). This distinction allows us to talk fruitfully about the difference between, on the one hand, activities in which groups of students get familiarised with a specific body of knowledge and, on the other hand, activities in which a group of students move, in a process of convergence, from individual perspectives on such a body of knowledge to a common understanding so as to make a common decision (see fig. 2).

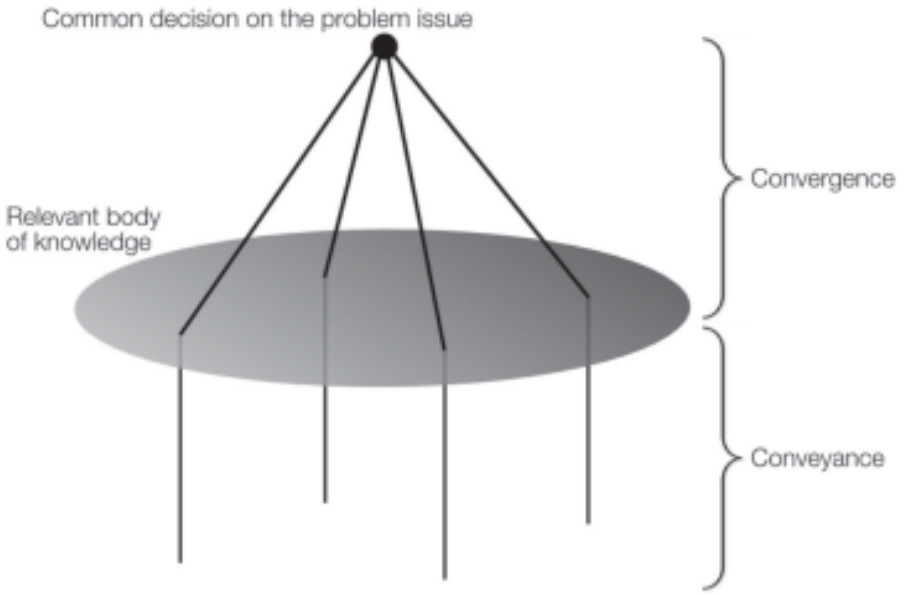

Fig. 2 – A visual representation of the place and role of convergence and conveyance processes in decision-making activities.

Needless to say, in the activities that I envision in this paper, these processes will in practice be deeply interwoven. This notwithstanding, the distinction helps us to articulate that when we place students in situations where they have to discuss a problem issue in order to reach a common decision, we are concerned with bringing them through sensible processes of convergence. In that sense, decision-making activities (as they are treated in this paper) presuppose that the participating students are already equipped to navigate the relevant bodies of science knowledge (i.e. they have been through the relevant processes of conveyance) and have established individual standpoints towards the problem issue that relates to that body of knowledge. In a slogan: the primary purpose of discussion activities is not the acquaintance with a body of knowledge; it is, rather, a contextualization of that body of knowledge by letting it play a part in the decision-making process.

Decision-making as a modelling process

In what has become one of the most influential works on students' decision-making in science teaching, Kortland argues that the generic model for decision-

making in many teaching contexts seems to be a "normative model" that looks "like a stepwise procedure of identifying the problem, developing criteria, generating alternatives, evaluating alternatives, and finally choosing and implementing the best solution" (KORTLAND, 2001, p. 36). According to Menthe (2006) such models are not only unrealistic in displaying the decision-making process of real persons; they are also too simplistic to be useful in school contexts, he argues. Menthe consequently reconstructs decision-making as a competence, and by involving action theory he proposes a concept of decision-making, according to which making a decision involves a "situational analysis, which is the *picture* or, in other words, the *map*, which the student constructs" (p. 33, my translation and emphasis). It is not coincidence that this description dovetails with representational terms (picture, map): An informed decision-making process involves constructing a "*model of the situation*", which involves a range of "alternative actions" to be taken in the situation, and when the decision is made one of these alternatives are chosen under the guidance of a specific set of negotiable quasi-personal criteria (*ibid*, my translation and emphasis).

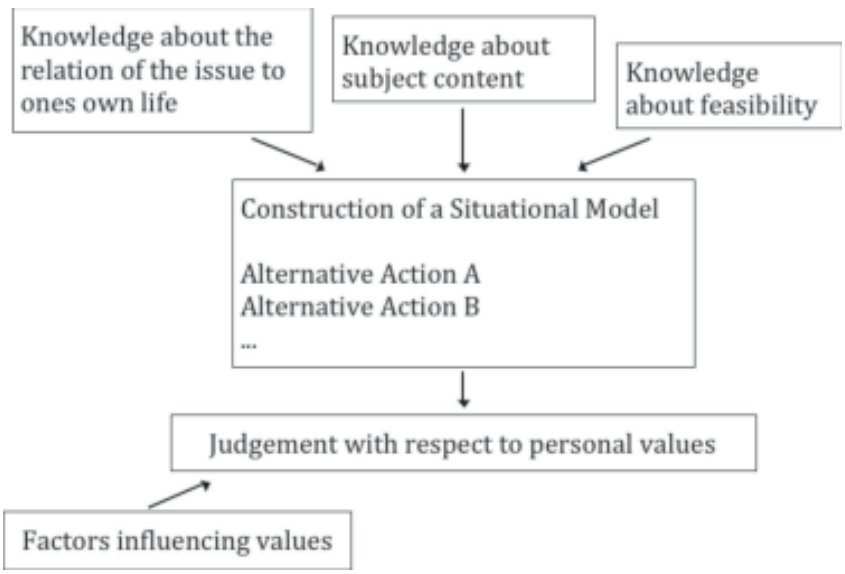

Fig. 3: The factors that influence the dynamic of a decision-making process. Adapted after Menthe (2006).

The prospects of conceptualising decision-making as essentially being a (inter)personal *modelling* process is of importance for the groundwork to be laid in this paper. For if we can understand decision-making processes as modelling processes it is to expect that we can take a SRC approach in the design phase and begin to make explicit which trajectories we foresee the students to follow. In other words: The SRC approach helps us to make explicit *that* it is appropriate to be mindful of the specific trajectories of the series of situational models the students construct trying to decide on a specific problem issue. And it is clear that the 'specific problem issue', I allude to here, is that which would correspond to the generative question in an SRC. I turn now to connect the notion of a generative question with the notion of a problem issues as both creating and structuring a critical discussion.

FROM ARGUMENTS TO CRITICAL DISCUSSIONS

The Toulminian paradigm

At least two reasons can be given for the centrality of the concept of argumentation in education research. First, being a critical citizen involves (among other things) to be epistemically empowered, which, in turn, means to be able to navigate a field of reason-giving practice (SELLARS, 1963). Second, from the perspective of certain theories of learning, activities in which students construct arguments can be beneficial for the learning of those students – the construction of arguments epitomizes, for instance, the externalization of inner episodes, which is so central for learning on Vygotsky's account (1978).

Until recently, the majority of approaches to argumentation in the science education community have so far belonged to what I want to call the *Toulminian paradigm*[3]. The basic tenets of this paradigm include not only a specific fashion of

[3] I construct the notion of the *Toulminian paradigm* as a way of making explicit a shared set of basic, and mostly implicit, assumption regarding how to understand argumentation. This, in turn, establishes a generic interlocutor for me to interact with in a critical disposition of different approaches to argumentation. A quick caveat on 'paradigm': There is a tendency of scholars to avoid the use of the term 'paradigm' when talking about the history of educational or argumentation studies. This is so, I take it, because, as Kuhn (1970) stresses, the term has an application in the experimental sciences. When talking about a specific paradigm one is indexing something in two dimensions; one points, on the one hand, at a specific set of assumptions or presuppositions and, on the other hand, at a specific practical context of rational experimental enquiry. I intend, however, to use 'paradigm' freed from its reference to the latter dimension and use it simply as a method of referring to a set of assumptions or presuppositions. Thus I wish to fit the usage of the term to the process of talking about non-experimental sciences or contexts of discussion such as educational and argumentation studies.

analysing argumentation, but also a specific way of understanding what argumentation is. Toulmin's model of argument patterns (TOULMIN, 1958) is a tool for analysing argumentation on account of the structural coherence between claims and their justifications: an argument is valid if the claim involved is endowed with epistemic authority though the citation of data, warrants, backings and qualifiers. To some extent, this model was *the* inspirational framework behind the analysis of argumentation in the first decades of argumentation study in science education. Thus many of the models that have been applied in science education research are *explicitly* derived from Toulmin's original model (see e.g. OSBORNE; ERDURAN; SIMON, 2004; ZOHAR; NEMET, 2002; ZEIDLER; SADLER, 2008). Notice that 'derived' is the proper term here, since it is recognized in the community that Toulmin's original model needs revision so as to be operational in science education research. (see esp. DRIVER; NEWTON; OSBORNE, 2000)

But, beyond being merely a collective application of similar analytical models, the *Toulminian paradigm* manifests an understanding of arguments as linguistic arrays of statements that should be analysed in terms of how, and with what success, their internal structure allows the transfer of epistemic authority from that which justifies to that which must be justified. To be sure, the fact alone that argumentation, in the *Toulminian paradigm*, is viewed as something that can be analysed without remainder in terms of its internal structure is not criticisable. But this rendition of argumentation is limiting the paradigm to consider only a specific trope of linguistic activities. Indeed, numerous critics – both within science education and argumentation theory – point to the shortcomings of Toulmin's model when we want to analyse argumentative *discourse* between two or more persons – in the *Toulminian paradigm* argumentation can solely be analyzed as being a monological affair (VAN EEMEREN; GROOTENDORST; KRUIGER, 1987; DUSCHL, 2008). We can illustrate the problems that this poses to an analysis of the discursive moves made by participants in discussions by noting a point made by Schlegoff (see e.g. 1988): discursive moves in conversations – hereunder I count discussions – are *sequential in nature*, which means that a thorough analysis of such moves must take into account how they were reacted to and how they were articulated with specific reactions in mind. Critical discussions are goings-on that are constituted by discursive *interactions* of participants, and by neglecting the role of argumentative moves in such interactions we preclude ourselves form getting the full picture of dialogic argumentation.

At this point it may be beneficial to remind ourselves of a well-known distinction between singular argumentative moves, considered as the end *product* of a chain of (inner) episodes of reasoning, and argumentative discourse, considered as the

social and dialogic *process* of articulating reasons in a critical discussion (see e.g. KUHN; UDELL, 2003; VAN EEMEREN; GROOTENDORST, 2004). To my mind, this distinction is as illustrative as it is dangerous. It is illustrative because it allows us to better understand what is meant with 'argumentation' within a given theoretical framework: in the *Toulminian paradigm*, for instance, argumentation is necessarily arguments as products, for, I would argue, no real meaning can be given to the process of articulating reasons. But the distinction is also dangerous, because it at times is introduced as a distinction in re (see e.g. JIMÉNEZ-ALEIXANDRE; ERDURAN, 2008); as if we can meaningfully talk about both senses of argumentation within one framework; and this, I think, is problematic. Again taking the *Toulminian paradigm* as an example, if we accept to study argumentation along such lines we are always already bound to analyse argumentative discourse *as if* it is consist of a series of singular argumentative moves.

The difference between these images of argumentation comes to the fore when we consider the quality of argumentation. Consider the following analogy. The term 'wall' is defined, in *The New Oxford American Dictionary*, both as being "a continuous brick or stone structure" and "a side of a building or room, typically forming a part of the building's structure". We are offered, that is, a structural and a teleological description of what a wall is: on the one hand, it is something that supervenes on having a structure consisting of an orchestration of bricks while, on the other hand, it is something that plays a role for the constitution of a building. When we now turn to consider what a *good* wall is, we should expect two very different descriptions. The first of which would sound similar to ' the good wall supervenes on a sensible orchestration of durable bricks', while the second would sound similar to 'the good wall is able to play a part in constituting a durable building'. In the translation from this analogy to the topic of this paper, 'wall' is interchangeable with 'argument', 'bricks' with 'the elements of an argument (claims, data, warrants, backings, rebuttals, and qualifiers)' and 'building' with 'critical discussion'. So that we are given two distinct descriptions of a *good* argument: (a) the good argument supervenes on the coherent orchestration of argumentative elements; and (b) the good argument plays a part in constituting a critical discussion towards the resolution of a difference of opinion. And it is this latter way of parsing argumentation that I want to focus on.

THE PRAGMA-DIALECTICAL THEORY OF ARGUMENTATION

As announced above, I want to focus on critical discussions, or, rather, on argumentative discourse as situated in a dialogic process in which two or more

parties resolve a difference of opinion and make a socio-scientific decision on a controversial issue. One theoretical framework that allows such a focus is the *pragma-dialectical* theory of argumentation according to which

> "[a]rgumentation is a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint". (VAN EEMEREN; GROOTENDORST, 2004, p. 1)

According to pragma-dialectics argumentation is a going-on that is instantiated through the discursive and social interaction between people; argumentation is launched by a (possibly implicit) difference of opinion and is directed towards resolving that difference of opinion. In other words: The pragma-dialectician understands and analyses arguments *as if* they were complexes of speech acts that play a role in a critical discussion (VAN EEMEREN; GROOTENDORST, 2004). This understanding is also the key behind the label 'pragma-dialectics' - i.e. a concatenation of *pragmatics*, the study of linguistic behaviour as it unfolds in a specific cultural-historical context, and *dialects*, the philosophical discipline of analysing critical discourse. (see e.g. p. 52)

The pragma-dialectician subscribes to four "core commitments" or "meta-theoretical principles" (VAN EEMEREN; GROOTENDORST, 1984, p. 4-18; 2004, p. 52-57) two of which deserve our primary attention. The principles of *externalization* and *socialization* imply that the analysis only targets the overtly expressed and externalised commitments by the speakers and such commitments are expressed as contributions to a socially situated communication process, respectively. For our purpose it is of interest to not the two following principles. The principle of *dialectification* prescribes that argumentation is "regarded as a regimented procedure for defending a standpoint against the critical reactions of a rational judge" (VAN EEMEREN; GROOTENDORST; JACKSON; JABOBS, 1993, p. 14). This has two notable consequences. First, it puts emphasis on the dialectical character of argumentation processes: Argumentation is not to be reduced to providing reasons so as to justify a claim; it also involves taking a critical stance towards the claims of the other party. In that sense it is this principle that places argumentation within a critical discussion that has the aim of resolving a difference of opinion. And it is here that we witness the real difference between the *Toulminian paradigm* and pragma-dialectics. Second, it provides as it were the procedures for securing that the resolution of the disagreement is obtained on *critical* grounds and not on random, coercive, or on relativistic grounds. The principle of *functionalization* prescribes, first, that argumentative moves are treated as *speech*

acts, and thereby that such moves belong to verbal actions that have a specific sort of *purposefulness* – i.e. they are performed with something in mind, namely resolving a difference of opinion; and, second, that the moves should consequently analysed in terms of which role they play in the process of resolving the difference of opinion. And it is this feature of pragma-dialectics that should interest us in particular. By categorising argumentative moves as being purposeful actions, we are allowed to treat their performance as being teleologically guided in a resolution process in a similar sense that we earlier regarded the exchanges in a controversy and the modelling activities in SRC activities. We are, in other words, allowed to treat controversies as a particular sub-type of critical discussions, and the resolution process (towards resolving a difference of opinion in the form of making a group decision on a controversial issue) that is at the core of such dialectical exchanges can be the object of educational designers with the implementation of the SRC approach.

We should, I think, let this theoretical apparatus behind the concept of a critical discussion guide us in attempts to design teaching activities that focus of critical discussions towards socio-scientific decision-making on controversial issues. From my perspective we can take with us at least two fundamental insights. First, since critical discussions in this approach always already aim towards resolving a difference of opinion the very act of placing student groups in a situation where they need to make a socio-scientific decision on a controversial issue is it self a way of structuring a critical discussion. Here we see a clear connection to ATD/SRC: the very act of introducing a suitable generative question goes a long way in the direction of structuring modelling activities. Second, it could be beneficial to facilitate and secure that the students, considered as parties, cover each stage in their discussion. And this includes the partial envisioning of the *trajectory* of a specific future discussion on a specific problem issue. Designing for constructive critical discussions in this light becomes scaffolding the discursive trajectories of students' argumentative discourse so that this discourse includes speech acts that play constructive roles in the process of resolving a difference of opinion. Once again an important bridge can be build to ATD/SRC. Being aware of the learning trajectories of the student is key in the design process: For the pragma-dialectician the notion of resolving a difference of opinion is the normative regulatory ideal – much akin to linguistic rules in general – that *tacitly* structures the interlocutors' conduct in critical discussion. Similar to how the generating question projects a trajectory through a subject area – this regulatory ideal projects a trajectory through a discursive field. In both cases the conduct of the involved persons is teleologically guided by an aim. In light of this, designing for critical

discussions towards decision-making becomes, *prima facie*, to articulate a specific problem issue to which there could be a difference of opinion and which is able to support a specific trajectory which abides by the theoretical structure of "ideal" critical discussions.

CONCLUDING REMARKS

In this paper I have argued that there is, on the conceptual level, a structural agreement between ATD/SRC and theoretical models of decision-making processes and critical discussions. The key point is that not only are decision-making process (*qua* their modelling nature) possible to design from a SRC perspective, critical discussions are processes in which the discursive practices of the discussants are teleologically guided by a regulatory ideal in a way much similar to how the ATD/SRC framework envisions that generative questions can guide the learning trajectories of students. In the first instance this puts an emphasis on the importance of the problem issue in the design of such activities. And although this is not novel information, the ATD/SRC framework can help us make explicit exactly what it means to transpose appropriate problem issues into the classroom context: namely, that appropriate controversial problem issues have the feature of what I have be calling *rich* and *forceful* – i.e. able both to generate a series of connected sub-problems and to teleologically guide the students through modelling processes that lets them decide on these problems through articulating the situational models in argumentative discourse.

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