Socioscientific issues via controversy mapping: bringing actor-network theory into the science classroom with digital technology

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ABSTRACT
What are the current challenges and opportunities for bringing actor-network theory (ANT) into issues-based science education? This article discusses experiences gained from introducing an educational version of ANT deploying digital technology into an upper secondary school science class. This teaching innovation, called controversy mapping, has been pioneered in different contexts of higher education before being adapted to school education. Experimenting with controversy mapping in a Swedish science class raised both conceptual and practical issues. These centre on: (1) how ANT-inspired controversy mapping redesigns the citizenship training enacted by institutionalized approaches to issues-based education as socioscientific issues (SSI); (2) how controversy mapping reconfigures the interdisciplinarity of issues-based science education; and (3) how controversy mapping displaces scientific literacy and knowledge of the nature of science as guiding concerns for teaching in favour of new preoccupations with digital literacy and digital tools and methods as contemporary infrastructures of free and open inquiry.

KEYWORDS
Actor-network theory; citizenship education; controversy mapping; digital technology; interdisciplinary science education; socioscientific issues

Introduction

Controversy analysis was central to the growth and consolidation of science and technology studies (STS) as an interdisciplinary field of academic endeavour. Over many decades now, such analysis has developed into a significant range of different approaches all of which are united in their ambition to re-envision the dynamics of science and technology (Pinch, 2015). Starting in the early 1970s, a bold new sociology of science emerged dedicated to studying scientific knowledge as ‘constitutively social all the way into its technical core’ (Pickering, 1992, p. 1). Thus, science was no longer conceived as inhabiting a separate domain of nature, facts, objectivity and reason, but as always intimately tied to culture, subjectivity, emotion and politics. Promulgating the socially situated nature of all scientific and technological knowledge claims, the new sociology of scientific knowledge famously adopted the ‘symmetry principle’ as a methodological guideline arguing that the same types of analyses and explanations should be applied to successful and unsuccessful
knowledge claims alike (Bloor, 1976). This principle was subsequently elaborated upon with the growth of actor-network theory (ANT) as an influential research programme within STS, and now far beyond. According to ANT, controversies should be recognized as important empirical occasions for investigating the production and stabilization of social and political entities as much as scientific and technological ones (Latour, 1992). Therefore, rather than imputing larger social and political interests as lying behind the settlement of scientific and technological conflicts, such interests are themselves envisioned as forged in the heat of controversy and the further entanglement of heterogeneous elements.

As STS and ANT-inspired analyses of the co-production of science, technology and society have become increasingly commonplace and influential across a continually growing range of disciplinary and interdisciplinary contexts, we aim in this paper to discuss and reflect upon some of the challenges and opportunities associated with bringing ANT into contemporary science education. The theory and practice of science education have hardly remained uninfluenced by STS and ANT and an interdisciplinary Science-Technology-Society reform movement has existed within the field for several decades. However, as we have recently experienced, introducing ANT into science education can still be a difficult educational innovation today. What are the reasons for this and how can obstacles to bringing ANT-informed teaching methods into the science classroom be potentially overcome? While we cannot pretend to have any definitive answers to these questions, we do believe we have some relevant knowledge to draw upon gained from experimenting with an ‘educational version’ of ANT, called controversy mapping, in a Swedish upper secondary school context. This knowledge and experience has led us to engage and grapple with a range of both conceptual and practical issues concerning the application of ANT to contemporary science education and it is the results of these engagements that we aim to outline and share in this paper.

Starting with conceptual issues, we have been obliged to confront how independently of the influence of STS and ANT, controversy analysis as a teaching method has followed its own developmental course within science education in recent decades. So-called ‘socioscientific issues’ (SSI) teaching is a global phenomenon today, and while several promising cases have been made for teaching SSI via ANT (e.g. Fountain, 1999; Pierce, 2015; Pouliot, 2008), other approaches have come to dominate. As we shall discuss, it is the emergence of SSI teaching alongside a broader and more functional notion of scientific literacy that has strongly shaped the character of controversy analysis in science education (Knain, 2015; Zeidler & Nichols, 2009). This close connection has meant that analysis is primarily dedicated to teaching students to distinguish the scientific component in controversies and learning how to make use of established facts and ways of reasoning to legislate over different claims and arguments (Sadler & Zeidler, 2009). Through this approach, science education becomes a form of citizen education mobilizing SSI as training grounds for the personal development of ‘responsible, evidence-based reflective judgement, conscience, and character’ (Zeidler & Nichols, 2009, p. 51). Such an emphasis on fostering individual capacities for informed decision-making preparing students for participation in science-based democracies contrasts significantly with the educational aims and ambitions that controversy mapping brings into the classroom. Due to its intimate connection to ANT, controversy mapping seeks to make use of digital technology to bring students into more immediate contact with on-going controversies as they
unfold. This is intended to produce an appreciation of how the object/thing at the centre of disagreements is often itself highly-contested, making it difficult to know which forms of reasoning and evidence to privilege over others. Thus, controversy mapping teaches respect for the complexity of issues, valuing the learning opportunities made available to students through their engagement with different collections of knowledges and interests in dispute. By asking students to describe, interpret and communicate what is of concern to different groups, controversy mapping is conceived as acting to expand students’ capacities for thought and reflection. This implies an alternative form of citizen education promoting the acquisition of what Dewey termed ‘social intelligence’ which can only be gained through interaction with, and direct participation in, matters of shared concern (Biesta, 2007; Dewey, 1909).

A second range of issues we have grappled with, and address in this paper, relates to the interdisciplinarity of science education today. In recent decades, the introduction of ‘issues-based’ teaching presenting science and technology as ‘embedded’ in society has led to growing acceptance of interdisciplinary science education. Curricular developments in Sweden promoting greater interdisciplinarity as well as prior experimentation with interdisciplinary teaching projects in the particular school we collaborated with were both important factors allowing us to bring controversy mapping into the classroom. However, the interdisciplinarity of SSI teaching is other than the interdisciplinarity advanced and enacted by controversy mapping. By not privileging the ‘scientific component’ in controversies, but rather embracing and respecting the complex relationality of issues, our teaching experiment heightened already existing tensions between participating teachers who either welcomed the new opportunity to challenge the limits of disciplinary learning, or saw our actions as further eroding and undermining the science content of science education.

A third set of issues we engaged with concerns the role and significance of digital tools and methods in contemporary science education. Controversy mapping coincides with a digitalization of ANT and one particular trajectory of ‘post-ANT’ development in the last 20 years or so. It is a pattern of development that brings ANT into contact with a collection of kindred initiatives across the social, media and computational sciences dedicated to developing and deploying new digital tools and methods in the study of collective life (Venturini, Jacomy, Meunier, & Latour, 2017). We found that this growing association between ANT and innovative forms of digital inquiry clearly enhanced the perceived relevance of our project as an innovative interdisciplinary approach to science education. We were able to partially ride a wave of curricular concern in Sweden pushing for educational reforms capable of further strengthening students’ digital competences and literacy. This meant that we were able both to equip students with digital tools for visualizing controversies, and to task them with assessing how digital technologies themselves might be implicated in the construction of controversies and both the science and the politics underlying them.

In the coming sections we will commence by outlining the rise of controversy mapping as both a technology-driven and educational version of ANT. This will be followed by a brief discussion of the growth of interdisciplinary issues-based teaching in science education through a Science-Technology-Society reform movement largely superseded today by an SSI movement. After further discussion of the development and growing uptake of controversy mapping practices we shall outline the design and execution of
our own school project including some of the views of participating teachers about the challenges it posed and the new opportunities it opened up. In conclusion we will summarize the different hybrid forms of science and citizenship education that SSI teaching and controversy mapping enact as well as reflect further on the importance digital tools and methods for the future of interdisciplinary science teaching.

Controversy mapping: a digitalization of ANT

ANT has always been a recipe for studying science and technology in the making. Also, given that reaching agreement over facts and the configuration of technological artefacts are processes granting modern societies their stability, ANT is also a recipe for studying these societies in the making as well. To observe and analyse science, technology and society continually under (re)construction, ANT has typically favoured an empirical focus on controversies to capture the dynamics of co-production more effectively. As originally outlined by Bruno Latour in *Science in Action* (1987), controversy analysis implies ‘following the actors’ and painstakingly detailing how these actors, scientists and engineers in the first instance, move through society enrolling other human and non-human actors to build networks capable of tipping the balance of force in their favour stabilizing (black-boxing) facts and artefacts (cf Latour, 1987, pp. 258–259).

By the mid-1990s ANT had become what John Law (2009) has depicted as a diaspora of material semiotics coinciding with an open and diverse collection of partially overlapping research traditions extending the intellectual legacy of ANT in different creative directions. One of these directions pursued in connection with Latour’s joining of Sciences Po in Paris and his creation of the Médialab there has been through the methodological and technological transformation of ANT into an experimental form of digital cartography known as controversy mapping (Venturini, 2010; 2012a). By forging new relations between the social sciences and digital engineering and design, Latour and colleagues have translated elements of controversy analysis into open source software packages which can be widely distributed and deployed by different user groups to observe and visualize web controversies of their choice. In the first instance this has given rise to a vibrant collection of university courses in controversy mapping around the world in locations as diverse as Paris, Amsterdam, Copenhagen, Manchester, Trento, Oxford, Lausanne, Cambridge Massachusetts and Rio de Janeiro (Venturini, 2010; http://controverses.sciences-po.fr/archiveindex/). Through intensive courses in the cartography of controversy, students are tasked with producing faithful depictions of the ‘magmatic’ landscapes of complex issues as they unfold (Venturini, 2010). The broader significance of such exercises in applied ANT, has been articulated further in transdisciplinary projects such as the EU 7th Framework project MACOSPOL (Mapping Controversies on Science for Politics) coordinated by Latour (www.mappingcontroversies.net). In rather optimistic terms, this project proposed that by equipping not only small groups of students with digital mapping tools, but citizens more generally, public participation and involvement in complex matters of concern could be powerfully promoted. More recently, however, this vision has been modified as closer collaboration between trained producers of controversy maps and targeted stakeholder groups has formed the basis for new transdisciplinary collaborations such as the EMAPS project (Electronic Maps to Assist Public Science) (www.emapsproject.com, Venturini, Ricci, Mauri, Kimbell, & Meunier, 2015).
However, as well as an educational tool and a new means of assisting public participation in science and technology, controversy mapping also implies new creative directions for research. As a form of radical empiricism committed to ‘following the actors’ ANT originally spawned rich and detailed historical and ethnographic accounts of how different coalitions of human and non-human agents competed to win control over the fate of facts and artefacts (Law, 2009). In this work, researchers were cautioned to resist introducing their own theories concerning the forces in play, and to suspend judgment as to who is right or wrong, in order to be better able to capture the unfolding dynamics of conflict and disagreement (Latour, 1987). Respecting these methodological sensibilities, the digitalization of ANT that controversy mapping brings can be seen as greatly enhancing and expanding its powers of empirical description. While previously limited to demonstrating the co-production of science, technology and society through the medium of individual case studies, new data mining and visualization tools create the opportunity to depict much broader landscapes of controversy without sacrificing attention to the smallest details of conflict and disagreement (Latour, Jensen, Venturini, Grauwin, & Bouiller, 2012; Marres & Rogers, 2005; Venturini & Latour, 2010). Furthermore, these tools promise to bring research into even closer proximity to science, technology and society in the making by enabling analysts to digitally monitor and visualize controversies as they are actually unfolding.

However, subscribing to the promise of digital media technologies for ANT has also led to a growing analytical focus on these technologies themselves as actors in controversies (Marres, 2015; Marres & Moats, 2015). As throughout the history of scientific visualization, using new media to map controversies begs the question: are we actually witnessing our object of investigation (the controversial issue at hand) or are we firstly seeing the influence of our means of visualization on its representation (e.g. the dynamics of search engines and social media platforms)? As Marres and Moats (2015) discuss, when using controversy mapping as an educational tool there has been a tendency to sidestep this delicate question by attempting to remove the worst-case examples of ‘digital bias’ from datasets (p. 6). However, when contemplating the future agenda for research, Marres (2015) in particular finds such a ‘precautionary’ approach wanting. Rather, she argues that the participation of digital media technology in the framing and articulation of issues should be treated as unavoidable and as an object itself for close empirical analysis extending to reflexive analysis of the agency of the controversy mapping community’s own software tools and methods. Just because, as Birkbak (2013) asserts, ‘the web is not an alternative reality, but an infrastructure deeply entangled with everything that goes on offline’(p. 24) so controversy analysis can be considered obliged to take the agency of digital technology seriously. Therefore, in some instances, controversy analysts will find it more relevant to approach digital media as crucial objects of study, while remaining content in others to accept them as highly valuable tools of analysis (cf. Marres, 2017, p. 141).

**SSI: crafting scientifically literate citizens**

As we have already mentioned, controversy analysis was pioneered in science education by a Science-Technology-Society (STS) movement that has been arguing for a more interdisciplinary ‘issues-based’ approach to teaching since the late 1970s (Fensham, 1985;
Zeidler, Sadler, Simmons, & Howes, 2005). Insisting that science should be envisioned as firmly embedded in society, this movement has claimed that the failure to do so can largely account for why the natural sciences and engineering have had greater difficulties attracting students than other subjects. Thus, STS teaching has been presented as having heightened the relevance and appeal of science education by addressing scientific and technological developments in ‘real world’ contexts (Aikenhead, 1994; Solomon, 1993). These efforts have then paved the way for a new SSI movement of reform. Proponents of SSI education claim to be ‘influenced by ideologies embedded in the STS tradition’ but dedicated to grounding their pedagogy more firmly in empirical research and a coherent developmental framework ‘that explicitly considers the psychological and epistemological growth of the child’ as well as ‘the development of character and virtue’ (Zeidler, 2014, p. 697; Zeidler et al., 2005, p. 357). To this end, SSI education is imagined teaching ‘at the extreme’ of a broader vision of scientific literacy where students are given opportunities ‘to experience science in contexts analogous to the contexts they may confront in their lived experiences’ (Sadler & Zeidler, 2009, p. 912). In these ‘science-related situations’ students are asked to actively participate ‘in developing argumentations skills, the ability to differentiate science from non-science issues, and the recognition of reliable evidence and data’ (Zeidler & Nichols, 2009, p. 49).

The skills for dealing with controversial SSI are also seen as hinging on the acquisition of ‘content-transcending knowledge’ about the nature of science and scientific inquiry in general (Kolstø, 2001, p. 292). This knowledge and the ‘habits of mind’ associated with it are then imagined capable of enabling students to appreciate the strengths and limitations of scientific knowledge in the context of SSIs and the other social, political and moral considerations which often need to be taken into account in processes of decision-making (Sadler, 2004; Wong, Wan, & Cheng, 2011).

Framing controversy analysis in this fashion and seeking to stage classroom engagements with SSI possessing scientific components capable of demarcation alongside a range of other contextual considerations has posed significant challenges of teaching module design. Therefore, just as controversy mapping courses have drawn ANT researchers into new arrangements of interdisciplinary and transdisciplinary collaboration, so SSI teaching has spawned similar styles of collaboration. SSI pedagogy has opened up new paths of professional development within science education itself and forged new connections between teachers, scientists and educational researchers (Zeidler, Applebaum, & Sadler, 2011). In parallel with the digital endeavours of controversy mapping, the development of SSI teaching has also seen the creation of new web-based resources and platforms creating a broader information infrastructure further enabling the uptake of this particular style of controversy analysis in the science classroom. One of the most prominent examples of this is the WISE Science platform established in 1997 and dedicated to designing, developing and implementing science inquiry activities under the support of the US National Science Foundation (https://wise.berkeley.edu). This Web-based Inquiry Science Environment platform hosts an open source library of inquiry-based projects from which students not only learn skills that prepare them to be successful in science, but also to ‘critique contradictory, persuasive messages in the popular press and on the Internet’ (Linn & Slotta, 2000, p. 32).
Maps and mapping: learning how to explore and represent controversies

As an educational version of ANT, controversy mapping is more concerned with mobilizing digital technology for exploring and visualizing the co-production of science, technology and society than fashioning the scientifically-literate citizen self. Controversies for ANT are matters of concern that fail to boil down to matters of readymade fact, as the issues and questions at the centre of disagreement typically remain undecided and open to combined scientific and political interpretation. Under such circumstances, focusing on the established facts of the matter, can be seen as often representing an attempt to avoid or sidestep greater controversy and subtract from its reality (cf. Latour, 2004, p. 232). Given these sensibilities, controversy mapping first emerged as a new tool of empirical research for ‘tracing the fate of issues and their publics on the web’ (Marres & Rogers, 2005). While such a web-based focus may have originally appeared as an interesting novelty, it is increasingly recognized today as highly motivated as the primacy of digital tools and infrastructures to the practice of science and politics alike has gained in appreciation.

As became apparent through pioneering research and education in controversy mapping, major disagreements on the web do not resemble conventional debates where different parties argue back and forth with each other. Rather they are enacted through competing ‘issue-networks’ offering alternative definitions of the controversial object at hand (Marres & Rogers, 2005; Rogers & Marres, 2000; Venturini, 2010). Usually, controversy will be sparked by a smaller number of actors who raise a new issue and attempt to draw attention to it. Often such efforts will come to nothing, but on other occasions an expanding heterogeneous issue-network will arise as a growing number and variety of actors (individual or collective; scientific, governmental or non-governmental) choose to subscribe and contribute to the formation of a new object of concern. Such an expanding issue-network may become so dominant that other networks defining the object differently find themselves reduced to dissenting minorities. At other times, however, the heat of controversy will be raised, as several competing networks succeed in winning support and visibility for starkly contrasting framings of the particular issue at hand.

Faced with such potential landscapes of disagreement, controversy mapping builds on the assumption that conventional standards of objectivity are unable to inform its practice. The scientific credentials and connections of competing issue networks will often be equally credible, and in other cases the research questions raised by a network will appear undeniably pressing, but currently unanswered. Given these circumstances, controversy mapping seeks to rely on what is termed ‘second-degree objectivity’ to guide its practice (Madsen, 2012, p. 56; Venturini, 2012a; 2012b). As Venturini (2012a) stresses, this does not imply adopting an attitude of complete impartiality towards competing framings of controversy, but rather a commitment to ‘attributing to each actor a representation that fits its position and relevance in the dispute’ (p. 798) at the time of analysis. If very many actors currently subscribe to a particular issue definition then this framing of controversy should be granted greater visibility on the map. In similar fashion, if an issue network succeeds in attracting the support of an established institutional actor such as a Parliament, or a state regulator or a well-recognized scientific institution then this should again be reflected in its cartographic representation. However, because the
variety of issue framings is also a measure of the scale of disagreement, it is important that majority voices are not allowed to completely colonize controversy maps. Thus, the distinctiveness of an issue definition may still warrant its cartographic representation even if only a few actors share it. For example, as Marres and Rogers (2008) point out, the rise of a more global issue-network may in some cases lead to the redefinition of the issue so that it no longer reflects the local framing that originally sparked it into existence.

Important institutions pioneering the development of the digital tools and equipment of controversy mapping have been, as mentioned earlier, the Médialab at Sciences Po in Paris and the Digital Methods Initiative at the University of Amsterdam (Venturini et al., 2017). Becoming a vehicle of diasporic creativity, controversy mapping has never been simply deployed as a means for teaching STS and ANT but has rather served to import the theory and practice of material semiotics into a broad range of higher educational circumstances. For example, it has been deployed for mapping controversies in architecture at the University of Manchester (Yaneva, 2012); environmental policy at the University of Oxford (Whatmore, 2009); techno-anthropology at the Aalborg University (http://www.tantlab.aau.dk/Projects/controversy-mapping/) and digital innovation and management at the IT University of Copenhagen (Ross Winthereik, 2016).

From 2012 attempts have been made to adapt and develop controversy mapping within secondary education as well. An important vehicle for this has been a major collaborative project called FORCCAST (Formation par la Cartographie des Controverses à l’Analyse des Sciences et Techniques - http://controverses.org/en/) led by Sciences Po and funded by the French National Agency for Research. Bringing together STS and educational researchers from France and abroad with software engineers, as well as teachers and students from a collection of French secondary schools, the aim of FORCCAST is to develop teaching methods for training different audiences in the exploration of controversies. For developing didactic interventions in schools, the aim is clearly to try and combine and reconcile the practice of controversy mapping with the citizenship education of SSI teaching. Thus, students are to be trained to explore and contribute to controversies by producing their own maps and video films representing disagreement, before being asked to participate in simulated debates where they assume and defend different stakeholder positions they have identified through the presentation of key arguments and supporting evidence (http://controverses.org/en/controversies).

In similar style, but on a more modest scale, a Swedish interest in introducing controversy mapping into upper secondary school education has also developed alongside French efforts. Once again, such an interest has arisen out of new transdisciplinary arrangements and the establishment in 2010 of the University of Gothenburg Learning and Media Technology Studio (LETStudio – http://letstudio.gu.se). This collaboration has brought together educational researchers concerned with learning in digital environments and STS researchers interested in new forms of public engagement and involvement in science, technology and medicine. These two groups of researchers soon identified controversy mapping as a fruitful focus for collaborative endeavour and contacts were made with both the Médialab in Paris and Danish developers of controversy mapping courses to discuss how teaching methods might be successfully adapted to a school context. Subsequently, a funding application was made to the Swedish Research Council for a project aiming to develop an integrated approach to controversy mapping and socioscientific issues teaching in an upper secondary school context (Mäkitalo, 2014).
Making a modest intervention in the science classroom

Upper secondary school science education in Sweden has acquired a relatively strong interdisciplinary profile in recent years. For example, the national curriculum for the 3-year Natural Science Programme is currently designed with two options: one placing greater emphasis on knowledge of biology, physics, chemistry and mathematics; the other as a Science and Society Programme with a further optional environmental profile. Reflecting the combined influence of the STS and SSI reform movements in science education, Science Studies (Naturkunskap) has also been established as a Swedish upper secondary school subject providing a ‘natural scientific citizen education’ (naturvetenskaplig medborgarbildning) focusing on issues of health, energy and sustainable development (https://www.skolverket.se). Following these developments, the national curriculum specifies that science teaching should provide ‘an understanding of how the natural sciences and society mutually influence each other’ as well as ‘the opportunity to discuss ethical dilemmas concerning the role of the natural sciences in society’ (https://www.skolverket.se).

Given these curricular concerns it has become commonplace for upper secondary schools to experiment with different forms of interdisciplinary teaching. The particular school that agreed to host LETStudio’s project in controversy mapping already had experience of developing shorter interdisciplinary teaching projects on their Natural Science Programme. Involving interdisciplinary teams of 4–6 teachers and typically 3–4 weeks in duration, these projects were designed to be clearly structured with detailed specification of the teaching goals addressed, the assignments to be completed and the grading criteria to be applied.

This established concern with planning and developing interdisciplinary school projects provided LETStudio with a format to relate to in order to collaboratively plan and implement a three-week controversy mapping teaching module. The science teacher (in physics and mathematics) appointed as leader of the project also came to act as a key mediator between the participating researchers and a digital methods tutor from the university and the rest of the interdisciplinary teaching team at the school. After a series of planning meetings, the project leader took responsibility for outlining the structure of the project that she chose to entitle ‘Tracking the Situation: Mapping Natural Scientific Controversies’. The participating researchers and teachers in the project collaborated in identifying several areas of contemporary controversy (e.g. fracking, electronic waste, human papilloma virus vaccines, animal testing in research and technologies of prenatal diagnosis) from within which students could identify current and on-going discussions during the mapping process. The project leader defined the overall task of the mapping exercise for the students as ‘not a matter of finding answers, but rather of exploring perspectives and divisions within a controversial field and the actors involved’. However, when specifying the relevant curricular goals to be addressed by the project, more of a balance between the aims of exploring and adjudicating between different perspectives was outlined.

With students working in smaller groups of 4 or 5, the project was divided into four distinct steps commencing with the work of producing a controversy map under the supervision of the digital methods tutor. This activity also encompassed the writing of a group memo describing the map-making process and the issues/actors identified for inclusion on the map. In a second step, the different groups shared their maps; comparing and
interrogating them together with other peer groups. Third, the students were asked to assume the position of actors represented on their maps and formulate arguments in defence of these positions at a classroom ‘press conference’. Finally, the students were asked to join a seminar where they were required to compare further the different controversies mapped and discuss how their knowledge of the natural sciences helped them to both communicate and evaluate the different arguments and perspectives represented.

Moving student engagement with controversy upstream

Building on the relative openness of the Swedish Natural Science Curriculum to both an SSI and an ANT approach to controversy analysis, how did the collaborative project sketched above work to combine, and partly reconcile, the differences between the two in practice? Broadly speaking, we approached controversy mapping and SSI teaching as bringing contrasting sensibilities to controversy analysis. Controversy mapping sees educational value in asking students to closely engage with controversies in order to explore and visualize their complexity. By embracing difference and complexity; seeking to interpret it and communicate it to others cartographically, students are believed to be acting to expand their capacities for thought and reflection and literally broadening their minds and intelligence. SSI teaching, on the other hand, acknowledges the complexity of controversies without valuing it in the same way. Rather, it is seen as a source of mystification and as something students need to learn to cut through by privileging the scientific component in controversies. Therefore, if controversy mapping asks students to describe and interpret the shifting entanglements of knowledge and interests, SSI teaching asks them to distil truth out of disagreement and demarcate reliable and acceptable claims from unreliable and unacceptable ones.

Given these contrasting sensibilities, it was decided to present controversy mapping as an ‘upstream activity’ addressing the eruption of controversy and its magmatic flow and SSI teaching as a ‘downstream activity’ as students were asked to assume a more evaluative stance towards different claims and arguments at both the press conference event and during the final seminar dedicated to analysing controversies in light of disciplinary knowledge of the natural sciences.

To successfully adopt and implement such an upstream-downstream framework the ‘digital bias’ of the mapping tools students were provided with proved helpful. For example, prominent among tools of controversy mapping are web crawlers which enable users to harvest and analyse hyperlink structures on the web. Reflecting the symmetrical sensibilities of ANT such devices are not designed to judge the reliability or credibility of different sources of online information, but to enable the building of datasets that can be used to detect and visualize different social and epistemological formations around particular issues. For our classroom project students were introduced to and instructed in the use of a relatively primitive web crawler called Navicrawler (http://webatlas.fr/wp/navicrawler/). Each student group was then tasked with using this software to construct a web corpus containing the hyperlink structure between roughly 400 websites pertaining to their chosen fields of controversy (Solli, Hillman, & Mäkitalo, 2017). These web corpora were then exported to an open source network visualization and analysis platform called Gephi (https://gephi.org) enabling students to produce network graph maps of nodes and edges depicting the variable connectivity of the different actors in controversy.
(See Figure 1). This was not an entirely automatic process, as students were required to qualitatively assess the relevance of including different websites in their web corpora prior to visualization. This work was structured by the task of writing a group memo where the assignment obliged each group to categorize the different actors found in controversy, specifying also who they are more or less densely linked with and the issue definitions they highlight. Although students were also asked at this stage to discuss how actors substantiated their arguments, they were still encouraged to apply standards of evaluation equivalent to ‘second-degree objectivity’ to capture the complexity of discussions and the variety of positions to be found. Thus, rather than asking the students to apply knowledge of the nature of science and scientific inquiry, the assignment encouraged what might be characterized as ‘moments of hesitation’ (Stengers, 2005) as groups had to explore further if data from certain websites promised to enhance the quality of their controversy maps or not.

**Interdisciplinary tensions**

The adoption of an upstream-downstream framework was embraced by the interdisciplinary team of teachers at our host school but still introduced new tensions into the work of this team. The concern with exploring and representing minority as well as majority voices in controversy remained in practice influential throughout the project work and while the press conference event asked students to critically compare perspectives and issue definitions, it also encouraged them to work further on interpreting and articulating these as well. Therefore, it was only in the concluding seminars that students were directly tasked with applying their knowledge of the natural sciences and the nature of scientific inquiry to evaluate different perspectives and the evidence supporting them.

In interviews that LETStudio researchers carried out with the teachers participating in the project, the fact that controversies were not initially presented as ‘science-related situations’ with a readily discernible ‘scientific component’ gave rise to divided opinions.

![Figure 1. A student working with Gephi visualization software to produce a spatialized network graph of actors engaged in controversy over hydraulic fracking.](image-url)
On the one hand, concern was expressed over the lack of effort to teach students the science immediately relevant to different controversies. The connection between disciplinary and interdisciplinary science teaching could be interpreted as broken. If students in parallel science classes were being taught the basics of human physiology, it was asked why the opportunity was not taken to deepen student engagement with this science when addressing controversies over vaccinations and practices of prenatal diagnosis and screening? The feeling that interdisciplinary teaching projects merely serve to dilute and erode the science content of the science curriculum led one teacher to summarize his disaffection with such activities as follows:

I don’t know if I believe so much in interdisciplinary work teams … I have previously been a university lecturer and have always collaborated with colleagues in the same discipline, not with the other teachers. I’m not particularly interested in what the students achieve in English or anything else. (Teacher 1, our translation)

In contrast to this, another participating teacher concluded that introducing controversy mapping into the classroom served to bring differing educational beliefs about knowledge and learning into direct collision with each other. Interdisciplinary projects could be appreciated as moving beyond the pedagogical limits of disciplinary learning and traditional forms of schooling:

Schools are actually very strange organizations as they pretend that knowledge is divided into different siloes, but in reality it’s not like that … It feels like you are working on a Death Star when you pretend that knowledge is that simple … For me you come to a limit in your own discipline … when it becomes much more interesting to broaden things … in religion you may be welcome to introduce ethics, but it cannot have anything to do with reality, because then you are getting into other disciplines … as soon as you start talking prenatal diagnosis, it’s ah sorry! That’s biology. It becomes ridiculous! When you reach a certain limit you simply must become more interdisciplinary. (Teacher 2, our translation)

As this teacher continued, she saw controversy mapping by its very design dedicated to highlighting the limits of disciplinary knowledge and exploring the fault lines between, for example, the social and natural sciences where disagreements are always liable to erupt.

**Digital literacies**

If controversy mapping itself proved controversial among the teachers helping to introduce it into the classroom, its promotion of digital literacy was broadly welcomed. This was all the more surprising as the software tools deployed proved harder for the students to use than had been hoped for during the planning of the project. Nevertheless, acting to strengthen the digital competences of students was accepted by all teachers involved as important and timely. One teacher dramatized the need for such competences as follows:

I have even greater difficulties these days than my students at identifying what is true and false on the net. I consider myself an expert on insect life, but every time I google about some insect so the most of what I find is wrong, or at least I think it is anyway. Written by happy amateurs. So I always, always warn my students when researching on the net to not just visit any page. I think the larger universities in Europe and the US are okay; Karolinska Institutet in Sweden, or at least until recent scandals. I try to implant in my students they should always, always be suspicious. (Teacher 1, our translation)
However, as well as powers of digital discrimination and the ability to sort between good and bad sources of information, the other teachers on the project were more readily able to appreciate the relevance of the digital skills of exploration and visualization that controversy mapping promotes:

I like how you can connect different sources to each other and see that many times the same larger actors are behind much information … that to take a simple example with GMOs with Monsanto as a huge actor working on many different levels and which many sources refer to without you typically realizing this. So there are power and economic interests behind much information that students would never discover, which you would never detect without working like this. (Teacher 3, our translation)

One teacher went further in arguing how the goal of developing digital competences could have been more closely integrated into the project. While the students were graded first in relation to their oral presentations at the press conference event and at the concluding seminars, a new version of the project might concentrate more on directly evaluating student’s abilities to digitally craft their maps and analyse the controversies more thoroughly in the process:

One could have done more with the maps themselves, used them more as tools and not just as a means to sort out and pinpoint actors as happened mostly this time. I think the maps could have been seen as more interesting from an analytical perspective if the tools had been used more open-mindedly and if they had been a little easier to handle technically. (Teacher 2, our translation)

Reflecting these varied sentiments and potentially enabling further digital interventions in the classroom similar to our own, the Swedish government announced in March 2017 the introduction of comprehensive curricular changes designed to strengthen the role of schools in developing student’s digital competences (Regeringskansliet, 2017). These changes aim to help students to not only develop their abilities to use digital technologies and understand the effects of digitalization for individuals and society, but also to cultivate critical and responsible relations to these technologies including appreciation of how information in digital media reflects underlying programming practices.

Conclusions

In this paper we have used our experiences from introducing controversy mapping into a Swedish upper secondary school to analyse both barriers and facilitators to bringing ANT into the science classroom today. This has led us to try and identify the differences controversy mapping can make to already established and institutionalized approaches to issues-based science education. SSI teaching through its close affiliation with a functional and applied notion of scientific literacy is dedicated to preparing students for lives of rational and informed decision-making in society. As a type of combined science and citizenship education it attempts to fashion students into scientifically-minded subjects capable of patrolling the boundaries between science and non-science. Securing the scientific integrity of such teaching is seen to demand strong continuity between disciplinary and interdisciplinary education as it is only by guaranteeing this that the ability of students to appreciate and respect the ‘scientific components’ in ‘science-related’ situations can be effectively fostered. Therefore, while efforts may be made to design classroom SSI
to be closely analogous to ‘real world’ controversies, the perceived educational value of these designs will remain dependent on whether or not students are able to dissect them into their different component parts (scientific, political, ethical, economic and so on).

By way of contrast, controversy mapping is not concerned with offering preparatory citizenship education readying students for participating in real world controversies. Rather it seeks to mobilize digital tools and media to transport such controversies into the classroom so that students can immerse themselves in and experience such disagreements as part of the school curriculum. In this way it can be argued that controversy mapping subscribes to Dewey’s vision of education for democracy and citizenship as best pursued through participation in democratic life itself (Biesta, 2007; Dewey, 1966).

Serving as an important source of inspiration for Latour’s (2004; 2005) understanding of controversies as matters of concern irreducible to matters of fact, Dewey (1966) viewed democracy as not just a form of government, but ‘a mode of associated living, of conjoint communicated experience’. This led him to believe that individuals will be best able to develop their intellectual powers and capacities when they actively participate in societies where many share and engage with the same concerns. Controversy mapping can be seen as a vehicle for sharing and communicating concerns which are already common to many. Through our school project students were drawn into engaging with controversies by being asked to cartographically represent them. Therefore, instead of working to break issues down into different component parts, students were asked to act as mediators of controversies describing, interpreting and representing them in a form communicable to others. In Deweyan terms, the maps constitute potential tools of social intelligence promising to help others see beyond more ‘partial and distorted’ issue definitions and think more freely and creatively about the matter at hand.

As Latour (2004) argues, matters of fact are only ‘very partial … very polemical, very political renderings of matters of concern’ (p. 232). This assertion can be used to reflect on how SSI teaching typically introduces controversies in the classroom as ‘science-related situations’ with clear cut ‘scientific components’ already known to the teachers leading the class. Bounding the knowledge relevant to controversies in this way and in the process of SSI module design risks limiting the opportunities given to students for engaging in freer forms of inquiry enabling them to discover and think through matters for themselves. Controversy mapping makes the relatedness of issues to science and politics just what students are tasked with interpreting and visualizing. While such an orientation renders the science content of classroom controversy analysis more undecided, it does not necessarily render it impoverished. Students’ digital inquiries could potentially reveal a richer and more varied number of established and tentative scientific components in controversies than had been initially envisaged.

If SSI teaching prepares students for citizenship by equipping them with a functional scientific literacy intended to enable them to act as rational autonomous decision-makers in society, controversy mapping implies another form of instrumentality. Instead of a guiding scientific literacy, it prizes digital literacy as the contemporary basis for lives of free and open inquiry enabling individuals to continue developing their capacities for thought and reflection (Mäkitalo, Solli, Ferraz Freire, & Elam, 2018 forthcoming). However, if digital tools and methods are to be understood as increasingly valuable citizen equipment for analysing the mutual entanglement of science, technology and
society today, then this technology in turn should not escape growing scrutiny. Controversy mapping promises to further extend the scope of interdisciplinary teaching in schools by pointing to the need to open up the black boxes of digital infrastructure and platform design for the futures of science, democracy and education alike.

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