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In Pursuit of Authenticity in Science Education

Abstract

This article presents a systematic review of how authenticity is used in science education research and discusses the implications these uses have for the design of science education classroom practices. Authenticity has been discussed in education for decades. However, the authenticity of science education not only concerns the design of educational activities, but also the content of what is being taught. This article reviews research articles published in 2013 and 2014, in the three highest ranking journals in science education, regarding how authenticity is framed in science education. The findings suggest that the uses vary greatly from referring to externally defined practices to student relevance. The findings are discussed with the notions of cultural and personal authenticity to suggest important aspects involved with designing science classroom activities authentic to the different references. Based on the review, we have developed a strategy for balancing authenticity in science education classroom practices between cultural and personal authenticity.

INTRODUCTION

In science education, the concept of authenticity has been used to argue against 'inauthentic' science education where the learning contexts are different in some way from the contexts where students have used or are supposed to use science (Levinson, 2013; Yeung Chung & Grace, 2010). Sometimes school science is argued to be alienated from what students experience as meaningful (Mayoh & Knutton, 1997), or how citizens generally use science (Aikenhead, Orpwood, & Fernsham, 2011). Other times, school science is instead compared with the practices of professional scientists (Miller, 1998; Sandoval, 2003). Another way to use the word authenticity is to argue for the involvement of students in real societal endeavours, including the involvement in producing work of direct use to society (Roth, van Eijck, Reis, & Hsu, 2008). This article reports on a literature review of how the notion of authenticity has been used in the science education research community.

Background

The notion of 'authenticity' was introduced as a qualitative descriptor of education in the mid-20th century. Since then, the notion has been used to argue for designing relevant and applicable teaching activities and for making more valid assessments of students' knowledge compared to traditional testing (Ashford-Rowe, Herrington, & Brown, 2013; Palm, 2008). Wiggins (1989; 1990) argues for the notion of authenticity as an attempt to preserve all the challenges in educational practice that would be involved with a relevant situation outside school. From Wiggins' perspective, authenticity in science education would potentially relate to the practices of professional scientists working in as well as outside universities and science-related citizen practices. Often, a more authentic approach to teaching is motivated from a theoretical perspective of knowledge as situated in social practices (Chang & Chiu, 2005).

The notion of authenticity in education is used loosely in the literature, sometimes referring to activities relevant for the world beyond the classroom and sometimes of relevance for learning within the classroom (Palm, 2008). Consequently, from one definition of authenticity, educational activities that develop participation for further science education (instant and long-term), but not necessarily for everyday life or a profession, could be considered authentic in relation to that educational system (Boud & Falchikov, 2006). However, authenticity is not only evaluated through how accurately activities reflect practices in or outside school, but also through how meaningful it is for the students to engage in the activities (Swaffield, 2011). When regarding authenticity as a concept of meaningfulness, participation in a science classroom activity becomes authentic when it becomes meaningful for the students to pursue. Consequently, what appears authentic to the teacher might not be authentic to the students (Gulikers, Bastiaens, & Kirschner, 2004).

Murphy, Lunn and Jones (2006) divided the notion of authenticity in science into the more fine-grained concepts of *cultural* and *personal* authenticity. Cultural authenticity deals with science learning as participation in an activity of a social context where understanding the nature of the scientific practices and skills, like designing experiments, is needed to participate in these activities. Murphy et al. describe cultural authenticity as lying in the practices in which students engage. However, this description can be understood as both something predefined in a practice and as a process of negotiation, as the student becomes part of a joint endeavour. Personal authenticity, on the other hand concerns individual meaning-making and evaluation of the intended learning objects, for example, the purpose for engaging in experimental design (Murphy et al., 2006). Personal authenticity thus refers to the relationships established in activity when the students engage with tasks. For a task to be considered personally authentic, Murphy et al. (2006), argue that performance must be perceived as relevant to the students when engaging in activities relating to science.

The aim of this article is to review how the notion of authenticity is used in the science education research community and discuss the consequences of different uses of authenticity for the design of authentic science education practice. The research question is:

- How is the notion of authenticity used in the science education research community?

METHOD

We have used a model for conducting systematic reviews developed by Bennett, Hogarth, Lubben, Campbell and Robinson (2010). The model consists of seven steps:

- (1) identification of review topic,
- (2) development of inclusion and exclusion criteria,
- (3) systematic searches in databases and other sources,
- (4) screening relevant studies against criteria,

- (5) coding against agreed characteristics,
- (6) providing a systematic map of the review area and
- (7) in-depth review of the selected studies in relation to the research questions.

The method is developed as a result of prior critique against more narrative reviews leaving readers at the discretion of the authors, with an increased risk of bias (Bennett, Lubben, Hogarth, & Campbell, 2005).

Screening relevant studies

We have limited the review to articles published in 2013 and 2014 in the three science education journals with the highest ranking in the SCImago Journal and Country Ranking (SJR) 2014. The SJR ranking system is a well-known ranking system of journals, not only taking into account the number of citations received but also the importance or prestige of the journals in which publications have been cited. The three highest ranking journals of science education in SJR were: *Journal of Research in Science Teaching (JRST)*, indicator 6,168 *Science Education (SCIE)*, indicator 5,262, and *Studies in Science Education (SSE)*, indicator 4,169. All other journals aimed specifically at science education were ranked significantly lower (indicator <1.8). Furthermore, the three reviewed journals cover the entire field of science education with all the scientific disciplines, as well as span over early childhood, primary, secondary and tertiary education. Some form of the word 'authentic' was used in many articles of the three journals and provided sufficient data for our analysis. However, expanding the review to other journals may have provided a different depiction of the frequency of various usages of the concept.

Inclusion and exclusion criteria

The criteria for an article to be included in the review was that some form of the word 'authentic' existed in the article. The word 'authentic' also constitutes the linguistic stem for authenticity, authentically and authenticate. This made it feasible to screen articles for the word. We have not included articles where other concepts associated with authenticity are used, such as relevant or realistic. The reason is that the authors of such articles do not make explicit claims concerning the concept of authenticity.

The two volumes of the three journals included 213 articles. Both research articles and book reviews were screened since both types of articles may contribute to the discussion of authentic science education. Out of the screened articles, a total of 97 contained some form of the word 'authentic'. In thirteen of these articles, 'authentic' only appeared in the reference list. Since these authors did not use the word themselves, these thirteen articles were removed from the sample. In sixteen articles, the word 'authentic' was used to describe the fact that the data collected derived from real classroom settings, that is, these authors did not refer to authenticity as a characteristic of science education. Thus, we have not included these in the review. In total 68 articles were included in the thematic coding.

Thematic coding

The term 'authenticity' was coded thematically with a focus on what words were used in combination with 'authentic', for example: scientific community (see Table 1). Some word combinations such as 'challenges' and 'transfer' frequently appeared together in the same sentence in different articles and were grouped as a category. This coding was reevaluated and redefined until the categories distinguished the article authors' different uses of authenticity. The coding, in turn, needed further confirmation to ensure that the combination was not random or used in conflict, for example, when criticising other researchers' use of authenticity. In some articles, 'authentic' was used multiple times, which sometimes resulted in the use of authenticity being coded into multiple uses. For instance, some authors used the term 'authentic' in combination with inquiry in one section of the article and in combination with scientists in another. In all, from the different meanings ascribed to authenticity in

one article, we interpreted that ‘authentic’ was used in a context of inquiry as an authentic practice of scientists. However, since other articles used inquiry without referring to scientists or used scientist without mentioning inquiry, the article was coded as both using authentic as inquiry practices and authentic as comparable with the practices of professional scientists.

FINDINGS

The categories that resulted from the thematic analysis of the different uses of authenticity in the reviewed articles included authenticity as:

- Comparable with practices of professional scientists
- Grounded in the world of students
- Involving inquiry practices
- Contributing to out-of-school-practices
- Involving a challenge of transferring knowledge
- Comparable with non-professional citizen practices
- Alignment with curricula and stated purposes
- Involving a pedagogy of caring between students and teachers

In most instances, ‘authentic’ was discussed in relation to secondary education (including middle and high school) (see Table 1). However, none of the articles mentioned that authenticity was particularly important for secondary school. Thus, the distribution of articles cannot be used to draw conclusions regarding whether researchers’ use of authenticity changes with the age of the students. However, primary (elementary) science received particular critique for being inauthentic in relation to the practices of professional scientists (Bathgate, Schunn, & Correnti, 2014; Chen, Hand, & McDowell, 2013; Feldman, Divoll, & Rogan-Klyve, 2013).

Table 1. Uses of authentic in different levels of science education

Authentic as...	Primary education	Secondary education	Tertiary education	Not specific
...comparable with the practices of professional scientists	8	17	5	8
...grounded in the world of students	1	7	5	7
...involving inquiry practices	4	9	3	2
...contributing to out-of-school-practices	0	4	2	3
...involving a challenge of transferring knowledge	1	2	4	0
...comparable with non-professional citizen practices	1	2	0	2
...alignment with curricula and stated purposes	0	1	0	1
...involving a pedagogy of caring relationships between students and teachers	0	1	0	0

The following subsections elaborate on the different categories and provide examples of what meanings were ascribed to authenticity within the different categories.

Authentic as comparable with the practices of professional scientists

In the reviewed articles, authenticity was most frequently used to refer to the practices of professional scientists. Within this category, authenticity was most often used to criticise what the authors labelled as conventional science education in order to promote alternative forms of science education with closer resemblance to the work of scientists. For instance, Nashon and Anderson (2013) criticise Nigerian schools as being driven by examination accomplishment. They give examples of how to create more authentic learning environments by collaborating with people from the science community. Feldman, Divoli and Rogan-Klyve (2013) also mention science teachers' limited experience of professional scientific practices as a constraint for developing authentic science education. Similarly, Chen, Hand and McDowell (2013) make a distinction between the authentic science of scientists and the science of elementary school, expressing a desire that elementary students should be provided feedback on their work from a real science community. Comparable distinctions are made by Bathgate, Schunn and Correnti (2014), who claim that students' negative attitudes towards science in the later school years could partly be explained by science education in the early school years as being too detached and differing from authentic science practices.

There is also a discussion on the risk of authenticity becoming superficial. Levinson (2013) criticises the use of the label 'authenticity' in a project where students met health-care personnel, since the tasks in the project were designed by teachers and therefore remained a school project. According to Levinson, the school's approach to science was too general; he argues for the need of a more profound restructuring in order to achieve authenticity. However, not all articles in this category discuss adopting professional scientific practices as an important element of science education. For example, Russ (2014) points out that striving to emulate the practices of professional scientist could only be claimed to be authentic if the overarching educational aim is the training of future scientists.

The authentic practices of professional scientists involved were often implicit. However, Kang, Thomson and Windschitl (2014) define elements of authentic science education that should be considered necessary, such as working with scientific claims, evidence, and reasoning. Kloser (2013) also identifies core authentic activities of scientific education, including the exploration of scientific questions, analysing data, and arguing claims. Kind (2013a) argues that a salient part of the scientific discourse is to critically examine scientific work. Therefore, this should be a part of science classroom activities. Patchen and Smithenry (2014), on the other hand, describe more socially interactive activities of collaborating, communicating, and critiquing as being characteristic of authentic science.

Authentic as grounded in the world of students

An alternative way of using authenticity is to look at how school science is grounded in the students' own questions and interests. For example, Christodoulou and Osborne (2014) write about authentic argumentations as argumentative situations where students work without direct influence from a teacher. They indicate that the presence of a teacher will make student learning less authentic. Smith, Wilson, Banks, Zhu and Varma-Nelson (2014) claim that student-centred authenticity is not individually generated, but rather negotiated through social interactions between students in developing a common language and understanding. Furthermore, Mestad and Kolstø (2014) use 'authentic language' to describe how students choose to talk *about* science in contrast to using a formal scientific language. They discuss authenticity in student language use as a descriptor of student ownership. Other articles present different aspects of autonomy. Enderle et al. (2014) as well as Zhai and Dillon (2014) describe cases of scientific internship as authentic because students are allowed to pursue their own research questions. These questions are important to the students, although they are not new to the scientific community they are visiting.

Authenticity, as grounding science education in the world of students, is sometimes argued theoretically. For example, Bhattacharyya and Bodner (2014) argue for using both constructivism and a situated learning approach to their research to study how students transform experiences from science laboratories to authentic endeavours in their own 'real world'. Similarly, Price and Lee (2013) write about the complexity of designing education in 'citizen science' for a multitude of practices in society; they referred to authenticity as grounding education in the practices of students' home environments.

Another dimension of grounding authenticity in the world of students relates to student identity transformations (Feldman et al., 2013). Rivera Maulucci et al. (2014) describe authenticity in terms of transformation of the student identity as a knower and producer of science. Another example is Jackson and Seiler (2013), who evaluate authenticity of assessments in terms of how well the assessments approach post-secondary science students as scientists. Some researchers use authenticity to describe student identity in opposition of the dominant discourse to the science classroom. Tan, Calabrese Barton, Kang and O'Neill (2013) specifically distinguished 'authentic science engagement' as embodied in student identity from actions that are interpreted as compliant with science classroom discourse. Similarly, Carlone, Scott and Lowder (2014) use the term 'authentic' to refer to whether students were being true to their 'roots' in a contradictory science class culture.

Authentic as involving inquiry practices

In this category, authenticity is used to refer to the inclusion of inquiry practices in science classroom practice. Here, inquiry practices are described as authentic when they facilitate the development of specific cognitive abilities (in contrast to when inquiry practices refer to activities in professional practices). For instance, Fallik, Rosenfeld and Eylon (2013) claim that inquiry tasks are authentic when they involve cognitive apprenticeship that develop non-memorisation and the integration of skills and knowledge as well as provide intellectual tools that are experimental and concrete.

Slavin, Lake, Hanley and Thurston (2014) describe a project where teachers are participating in a program of developing inquiry skills for a more authentic evaluation of science education. Wendt and Rockinson-Szapkiw (2014) state that authentic hands-on inquiry activities is an effective way of developing teachers' strategies for helping students use prior knowledge to construct a new understanding of science. Yoon, Elinich, Wang, Schooneveld and Anderson (2013) describe the possibilities for studying how students use prior experiences to understand science in inquiry practices.

However, Rivera Maulucci, Brown, Grey and Sullivan (2014) criticise calling classroom inquiry tasks authentic. They criticise classroom inquiry tasks for being constrained by curricular goals of developing specified knowledge. Instead, they argue that authentic inquiry practices must be open-ended, allowing students to define and develop their own purposes, scientific procedures, and scientific knowledge. This use of authenticity connects to authenticity as grounded in the world of students. Additionally, Gray (2014) criticises a traditional view of science as a solely laboratory-based practice. He argues that an authentic inquiry practise must also include scientific problems that cannot be dealt with experimentally.

Authentic as contributing to out-of-school practices

Sometimes, the term 'authenticity' is reserved for instances when students make contributions to out-of-school practices. In this category, the notion of *audience* is central. Dauer, Momsen, Speth, Makohon-Moore and Long (2013) point out differences between building biological models as a school task and building biological models as part of a practice where molecular models are needed to explain evolutionary outcomes to a real out-of-school audience. Similarly, Sampson, Enderle, Grooms and Witte (2013) argue that there is a need for a real audience if the documentation of scientific work is to become authentic. Another example of reference to an authentic audience is Polman, Newman, Saul and Farrar's (2014) description of a project where students are allowed to publish texts with a scientific content for the local community.

Authenticity in this category also refers to the potential impact that working with a local community may have on the students themselves. Stroupe (2014) claims that authentic science involved students positioning themselves as ‘conceptual agents’ rather than information receivers, where they produce the scientific knowledge needed for explaining the context. Birmingham and Barton (2014) report from a project where students could engage in local energy and environmental issues and communicate their work to the community of which they were a part. Another example is a project where citizens were invited to contribute with their expertise and provide input knowledge in a project run by scientists (Price & Lee, 2013). The authenticity of the project is pointed out due to citizen engagement in solving issues that were of common interest to the community and not only what was personally interesting to the participants.

Authentic as involving a challenge of transferring knowledge

This category includes authenticity as a transfer of knowledge from familiar to new contexts. For instance, Kuo, Hull, Gupta and Elby (2013) use ‘authentic sense-making’ to describe tasks requiring transfer between intuitive ideas and formal representations; when students use symbols of science to understand new problems as opposed to rote procedures. Lee et al. (2014) describe authentic problem-solving activities of autonomous problem solvers as the critical evaluation of information obtained from others, and the transfer and development of their scientific knowledge. Yadav, Vinh, Shaver, Meckl and Firebaugh (2014) similarly refer to the transfer of knowledge when describing the authenticity of science in engineering education. Students are challenged to identify what is necessary to learn and how to apply and transfer that knowledge to new application areas. This use of authenticity is thus closely connected to the use of authenticity with reference to professional scientific activities. However, instead of trying to adopt repertoires from engineering communities, students are challenged to figure out their own way to deal with out-of-school contexts.

Authentic as comparable with non-professional citizen practices

A few articles refer to public issues or citizens’ use of science. Price and Lee (2013) recognise the complexity of making science education authentic in relation to a diversity of citizens’ practices. Kloser (2014) describe a project where students are working with ‘authentic texts’, meaning non-scientific journal articles with a scientific content. Stuckey, Hofstein, Mamlok-Naaman and Eilks (2013) argue for authenticity in relation to socio-scientific issues, where the content is formed by public interests. Grimberg and Gummer (2013) use community members mastering cultural practices to find intersection points between tribal, science, and school science cultures and achieving authenticity to public everyday life. One dimension of this category refers to treating science as integrated rather than separate subjects. For example, Gresnigt, Taconis, van Keulen, Gravemeijer and Baartman (2014) write about ‘authentic science contexts’ as contexts where science is not divided into different subjects. They argue that in the public use of science, chemistry, physics and biology are integrated.

Authentic as alignment with curricula and stated purposes

This category refers to authenticity as a concept of curriculum theory which is used to evaluate the alignment between the lesson activities and the purposes stated in, for example, curricula and syllabi. This category was found only in two articles. Stuckey et al. (2013) claim that one educational practice is authentic when there is alignment between goals, curricula and pedagogical aims. Similarly, Lee et al. (2014) propose a notion of authentic measurements, referring to assessment where there is alignment between the specific assessment task and the formative purpose of assessment.

Authentic as involving a pedagogy of caring relationships between students and teachers

A unique use of authenticity is proposed by Rivera Maulucci (2013), who describes ‘authentic pedagogy’ as a pedagogy focusing on establishing caring relationships between students and teachers with an aim to engage students more deeply in school work.

DISCUSSION

In sum, we found that, in the analysed science education journals, it was most common to use *authentic as comparable with the practices of professional scientists*. In this context, the term was used to criticise traditional science education. Authenticity was used to argue for developing students' interest in pursuing further education in science or introduce scientific working methods. This use of authenticity was sometimes combined with descriptions of teaching *involving inquiry practice* as authentic. However, the authenticity of inquiry was justified with claims that students would develop a deeper understanding of science through inquiry activities, and teachers would be able to observe students' understanding more easily. On the other hand, another common usage was *authentic as grounded in the world of the students* rather than in predefined practices. Authenticity as such would be expressed through interest, relevance and autonomy of students or students forming an identity in science class. The fourth most common use of authenticity was to describe activities in science education *as contributing to out-of-school practices*. Students' work was framed as authentic when the students had generated something themselves to a real or imagined outside audience. Claiming science tasks to be *authentic as involving a challenge of transferring knowledge, as comparable with non-professional citizen practices, or as alignment with curriculum and stated purposes* were less frequent. Only one article presented the notion of *authentic as involving a pedagogy of caring relationships between students and teachers*.

The use of authentic as comparable to the practices of professional scientists or citizens (other than scientists) strongly emphasises cultural authenticity (cf. Murphy et al 2006). However, designing education culturally authentic to, for example, professional scientific practices, involves not only the challenge of finding scientific tasks simple enough for the students to manage, but also deciding which scientists' practices should be transferred into the school context. For instance, Knorr Cetina (1999) describes how the practices of high-energy physics research and microbiology research can vastly differ. Within specialised courses in tertiary education this would be less of a problem than in primary education, which has many other purposes than the education of future scientists (Russ, 2014). Moreover, it is important to point out that many of the studies reported from projects of cooperation between scientists and schools. Without the expertise of scientists, there is a risk that science education would contribute to misrepresentations of what would be culturally authentic to practices of the science community. However, teachers can design culturally authentic school activities by emphasising abilities commonly valued by the science community such as, for example, abilities to reason about explanations, claims, and evidence, critical examination of scientific work as well as collaboration (Kang et al., 2014; Kind, 2013b; Kloser, 2013; Patchen & Smithenry, 2014).

The uses of authenticity with references to the world of students, the challenges of transfer, and the pedagogy of caring, are in line with Murphy et al.'s (2006) notion of personal authenticity. Such references concern how students relate to science in the classroom. Designing personally authentic science education becomes difficult because personal authenticity is evaluated through how meaningful and challenging engagement in the school activities becomes to the students. Consequently, it is difficult to predict beforehand. There is a risk that science education will lose personal authenticity to the students if what is valued as quality in school science education practice does not concur with the students' experiences of participation in those contexts (Knain, 1999). According to Gazley et al. (2014), this negotiation between student and science culture in the science classroom is important for the students' future educational and career choices. This indicates that personally authentic science education should provide students with information useful for making such choices.

Schoolwork is commonly designed by teachers (or sometimes the students themselves) using predefined criteria. Thus, designing authentic school activities where students make authentic contributions implies a complete reframing of education. When students contribute to out-of-school practices, they simultaneously become accountable to those communities, as there emerges a need for students' contributions to become useful to the community (Carlgren, 1999). Consequently, taking a step towards

culturally authentic participation of contribution means taking a step away from the school as an arena where students can practice participation without the constraints of accountability (Ibid.) To some extent, this dilemma is circumvented in tasks where students are mainly held accountable for contributing to their own scientific work. One example is given in an article by Dauer et al (2013) where students had to present work to an out-of-school audience. However, if the students are asked to produce useful scientific material for the greater public, they will have much fewer opportunities to explore, for instance, different methods, since they must comply with public expectancies. Another dimension of contributing to practices is the personally authentic aspect of students experiencing that what they do actually may have an impact beyond the classroom (Stroupe, 2014).

The different uses of authenticity have very different implications for educational design. Science education emphasising cultural authenticity might not become very personally authentic. For instance, emphasising cultural authenticity and the comparison with scientists' practices might have negative implications for personal authenticity and the possibilities to establish a teaching practice that is sensitive to students' interests. A challenge is therefore to design activities that are both culturally and personally authentic. One possible strategy to deal with this tension is to use a variety of alternative tasks that are authentic to a variety of contexts and communities of practice. A variety of tasks could mediate negotiation between personally authentic identity and culturally authentic membership in different communities using science (Jackson & Seiler, 2013), as well as between personally authentic cognitive development, and culturally authentic repertoires of scientific inquiry practices (Slavin et al., 2014). They could also afford personally authentic self-expression and culturally authentic contributions to students' communities (Birmingham & Calabrese Barton, 2014; Price & Lee, 2013). By taking into account both personal and cultural aspects of authenticity in the design of a variety of tasks, science education could contribute to better supporting students in making sense of both the cultural contexts of scientific practices and their personal relations to those activities.

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