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International Views of Authenticity in Integrated STEM Education

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Abstract

Integrated STEM education aims for teaching and learning that goes beyond the individual disciplines of science, technology, engineering, and mathematics. Although authenticity is a widely used term in the literature, little is known about the meaning and application of the concept. The aim of this study is to systematically explore international views of authenticity in integrated STEM education. An online survey was responded to by twenty-eight experienced researchers and practitioners in science, technology, engineering, mathematics as well as related educational disciplines from around the world. We labelled the acquired participants the STEM expert panel, with expertise in STEM education, curriculum development, and the STEM root disciplines. The STEM expert panel responded to three open-ended questions that probed their opinions concerning opportunities and limitations of integrating the STEM disciplines. Data were analysed thematically and iteratively to reveal salient categories of authenticity. In terms of findings, views included three overarching themes. Firstly, experts opined that integrated STEM education requires authentic, real-world problems that support innovative and critical thinking capabilities in students. Secondly, real-world STEM education scenarios are in the panel's view primarily technology and engineering based. Thirdly, model-based integrated STEM education approaches provide opportunities to include real-life solutions and genuine problem solving that are not otherwise possible. Consequently, what is meant by authenticity and authentic learning was addressed, not for whom something is authentic. Findings also suggest that although the international STEM experts often foregrounded 'S' and 'M' principles in their descriptions of STEM education, the 'T' and 'E' emerged as fundamental to implementing authenticity. Thus, the panellists viewed technology and engineering as providing authentic contexts that act as bridges between school and real-world settings.

Key Words: Authenticity, STEM education, Experts' views, Technology education, Engineering education

1. INTRODUCTION

Although authenticity is a widely used term in the literature, little is known about the meaning and application of the concept in education. The concept sometimes refers to the emulation of real-world practices in school settings, but it can also denote – often interdisciplinary – education dealing with complex problem solving that is supposed to stimulate students' creativity and innovativeness (e.g., Herrington & Oliver, 2000; Lombardi & Oblinger, 2007). Authentic learning thereby shares many similarities with, for example, project-based and problem-based learning, but a more specified definition of what is really *authentic*, and *for whom* something is authentic, is needed (Nicaise, Gibney & Crane, 2000; Snape & Fox-Turnbull, 2013; Svärd, Schönborn & Hallström, 2017). According to contemporary views, integrated STEM – science, technology, engineering, and mathematics – education aims to achieve learning that is authentic because it is based on the integration of knowledge that occurs in real-world practices in these disciplines (e.g., Hallström & Schönborn, 2019; Kelley & Knowles, 2016); that is, an integrated STEM literacy (Tang & Williams, 2019). Consequently, one viable way of studying and potentially clarifying authenticity in education is by turning to experts engaged with integrated science, technology, engineering, and mathematics education projects. The aim of this study is to systematically explore international views of authenticity in integrated STEM education.

2. METHOD

The study used an online survey to obtain a panel's views on integrated STEM as an educational enterprise at large. Twenty-eight experienced international researchers and practitioners in science, technology, engineering, mathematics as well as related educational disciplines, hereafter referred to as the *STEM expert panel*, participated. The panel represented three STEM areas (some participants had expertise in more than one area), namely (i) researchers in the fields of science, technology, engineering, and mathematics education, (ii) STEM education actors such as teacher educators, curriculum specialists and policy makers, and (iii) STEM professionals such as engineers and designers working primarily in industry. The panel responded to an anonymous questionnaire with three open-ended questions, of which one specifically addressed the role of authenticity in integrated STEM education (cf. Khatri, Henderson, Cole, Froyd, Friedrichsen, & Stanford, 2017): 'Provide and motivate an example based on your own work experiences where modelling is involved in an authentic, real-world relevant STEM learning or work scenario.'

We performed a qualitative content analysis. Mayring (2000) specifies two main approaches to qualitative content analysis, namely inductive category development and deductive category development. In this paper we implement the former inductive approach, and, as such, it is based on a hermeneutic tradition of text interpretation. The approach includes repeated reading of the data set to find and establish patterns. The repeated reading resulted in a step-by-step formulation of inductive categories, which after the last round of the analysis were reduced to three main themes (Mayring, 2000).

3. FINDINGS

The following three sections describe the international panel's views on authenticity in integrated STEM education, in relation to the three overarching themes.

3.1. Integrated STEM education requires authentic, real-world problems that support innovative and critical thinking

The STEM expert panel was of the view that integrating the STEM disciplines requires students to solve real-world problems that require critical and complex thinking. A typical quote exemplifying this theme was as follows:

> The opportunities that I envision are that integrated STEM learning experiences can allow students to acquire authentic and sometimes even complex learning experiences that will prepare them better to face global challenges. (Expert 9)

As shown in the quote above, preparing students for global challenges relies on integrated STEM learning. Indeed, the significant role of integrated STEM for developing real world knowledge is further supported by the following panellist's view:

> The benefits of having STEM as an educational construct include an acknowledgement that knowledge in the real-world is integrated and interdisciplinary collaboration is commonplace. (Expert 2)

Overall, as eloquently captured by the following excerpt, integrated STEM foundations provide opportunities for learners to develop their critical thinking, innovative and creative thinking skills (Kelley & Knowles, 2016):

> With a foundation in these subjects, a STEM career allows you to solve problems, develop new ideas and conduct research. STEM teaches the students to be critical thinkers, innovative and creative. The focus on logical thought processes and problem-solving allows students to develop mental habits that will help them succeed in any field. STEM coursework challenges students to think critically and come up with their own solutions. (Expert 25)

Apart from identifying the importance of innovative and critical thinking skills, the respondent above also emphasises that these skills can facilitate the development of cognitive tools that can support efforts in multiple course and career contexts.

3.2. Real-world STEM education scenarios are technology and engineering based

The responses suggest that real-world integrated STEM initiatives are also often based on technology and engineering practices (cf. English & King, 2015). One expert mentioned such an example, where the engineering design process is prominent:

> Students also engage in engineering practices by designing systems, devices or processes, and iteratively test and optimize them by simulation. By integrating computation in this manner, students are engaged in the entire modelling cycle starting from creating, using, evaluating, and revising models, at the same time as they engage in multiple STEM practices such as inquiry skills, argumentation, design, model-based reasoning, computational thinking, and simulation practices. (Expert 9)

Different kinds of modelling such as testing, simulation and optimization also feature in such design processes, by going through the 'modelling cycle' including designing, using, evaluating, and revising such models. It is notable that 'computation' and 'computational thinking' are seen as fundamental for carrying out the modelling (Denning & Tedre, 2019).

Although the examples that the panel put forward mainly come from technological and engineering design, they also emphasise that these are authentic STEM activities and as such they should relate to all four disciplines. Consequently, one expert described such an activity in this way:

> An example of an integrated STEM activity could include the design and modelling of a home solar system. Students would need to know the principles of science used to convert the sun's energy into solar power. They would need to mathematically calculate the energy that needs to be collected/processed to operate the mechanisms that the solar power would operate. They would need to engineer the slopes needed to catch the most solar power. (Expert 4)

So, while integrated STEM projects in the experts' view could be said to be technology and engineering based, the projects would also need to consider scientific and mathematical dimensions and/or practices in order to be fully successful and authentic (cf. Nordlöf, Norström, Höst, & Hallström, 2021).

Sometimes, however, the responses also suggest that technology and engineering modelling are implicit in integrated STEM initiatives, at the same time as the intended learning outcomes primarily relate to traditional science and/or mathematics content. One participant mentioned such an example:

> I'll refer to a student projects in which four students worked on restoring distorted photographs. […] Firstly, a photo is in and of itself a (visual) two-dimensional model of a three-dimensional world based on perspective constructions, which can be analysed in terms of classical projective geometry. Secondly, photos can be modelled by a variety of different mathematical tools so as to provide a digital representation of them (the JPEG algorithm is the best-known example of this), representations that can be transmitted electronically. Such representations make it possible to restore distorted images by making use of inverse Fourier and Radon transforms. The student group referred to wanted to learn to make such restorations both in theoretical and in practical terms. […] Completing the project generated authentic experiences of coming to grips with different sorts of models. They also experienced the complex interplay between different STEM fields when going into depth with characterising, representing and manipulating images by way of mathematical representations. (Expert 11)

Either way, even these kinds of projects could be clearly labelled integrated STEM projects with a taste of engineering design, which are made authentic by including all four disciplines in real-world modelling activities (Hallström & Schönborn, 2019).

3.3. Integrated STEM education approaches that employ modelling provide opportunities to include real-life solutions and genuine problem solving that are not otherwise possible

Real-life problem solving seldom follows traditional disciplinary borders but demands a variety of skills and knowledge. The panel highlighted how integrated STEM projects thereby provide opportunities to use more realistic tasks than assignments that are possible in traditional teaching:

> Through learner integration of knowledge drawn from these four subjects, they approach problem solving as it is done in real world situations. This shows them how to use what they know, or can research, to solve all problems they encounter in school or in life. This results in authentic learning. (Expert 4)

Modelling is important to achieve this because models serve as representations of both the problem domain and of the suggested solutions (Gilbert, 2004). The degree of simplification varies between problem domains and with students' expertise, as does the type of model. Some of the respondents stress the need for prototypes and physical models, which can provide students with a tangible experience related to the problem and its solution:

> For example, designing protective textiles such as warm and dry clothing for trawlermen. Different materials would be modelled for their insulation and water-resisting properties. Then, what fabrics or fabric combinations have the desired properties and how should they be fairly investigated? (Expert 13)

In this case, the characteristics of a garment are determined by measurements on a model consisting of small pieces of the proper material. In other cases, the models are symbolic or consist of drawings or 3D objects in reduced size. To be able to create, use, and analyse models of varying kinds is in many cases necessary to gain insight into real-world problems and their possible solutions:

> The making of prototypes was also a modelling process, as the actual commercial products that they were modelling would be manufactured using more sophisticated processes, materials and equipment. (Expert 2)

Apart from physical and visual models, several respondents mention the necessity of mathematical modelling. Using mathematical models in STEM projects is described as a way of connecting abstract, context-free mathematics skills learnt from textbooks to the less orderly real world outside of the school walls. Examples range from rough estimations to simulations and statistical analyses. The modelling process is an opportunity to include mathematics in projects that are predominantly science and/or technology based (Kertil & Gurel, 2016; Vos, 2011). One respondent provided the following list of examples:

> Estimation problems with, e.g., examples from biology (e.g., humans and animals) involving physics (e.g., mechanics, energy, heat), technology (e.g., measurements in sports) and mathematics (e.g., order of magnitude) and dealing with real-life issues. (Expert 8)

Apart from being useful in the solving of realistic integrated STEM problems, mathematical modelling is also highlighted as a method of practicing mathematical skills and increasing mathematical understanding (English, 2022; Niss, 2012):

> Mathematics is the toolbox used in other subjects, to describe and predict phenomena by modelling these phenomena, and eventually solve real-life problems. So, modelling is an activity which aims at solving real-life problems, and the means in which this is done is through mathematical models. […] One the one hand, students learn to use and appreciate mathematics as a tool in other subjects. On the other hand, the contextualized (situated) mathematics supports many students to better understand mathematics. (Expert 3)

In sum, the STEM expert panel emphasizes how integrated STEM education can enable the inclusion of more realistic problems in education, and the necessity for proper models and modelling exercises in this endeavour, for example, from mathematics.

4. CONCLUSIONS AND IMPLICATIONS

The international STEM expert panel revealed three main views on authenticity in integrated STEM education. Firstly, respondents opined that integrated STEM education requires authentic, real-world problems that support innovative and critical thinking capabilities in students. Secondly, real-world STEM education scenarios are viewed as primarily technology and engineering based. Thirdly, model-based integrated STEM education approaches provide opportunities to include real-life solutions and genuine problem solving that are not otherwise possible. Therefore, what is meant by authenticity and authentic learning was what the panellists primarily addressed, not for whom something could be regarded as authentic.

The identified themes raise several implications for approaching authenticity in education in general, and in STEM education in particular. The integrated STEM education examples that the panel provided were mostly interdisciplinary engineering design projects where three or four of the STEM disciplines were represented. Therefore, concerns of possibly ‘watering down’ the individual disciplines due to integration should be carefully considered. However, it is also important to illuminate the examples of already integrated, yet implicit, cooperation. Strategies for making such examples explicit could take the shape of integrated STEM projects that are specifically based on the engineering design process (e.g., Lin, Wu, Hsu, & Williams, 2021), although it is important that as many STEM disciplines as possible are included to maintain authenticity. It is notable that many experts emphasised the centrality of mathematical modelling for achieving authentic, integrated STEM education (Kertil & Gurel, 2016), and that computational support was mentioned as important for successful modelling (Denning & Tedre, 2019; Hallström & Schönborn, 2019).

Furthermore, the international panel expressed that integrated STEM education not only requires authentic problems to make it connected to the real world, but also provides opportunities for real-life solutions. Modelling stands out as a valid strategy towards such solutions (Gilbert, 2004). This strategy requires providing teachers with the necessary skills and opportunities to include their original knowledge in an integrated STEM context which encourages collaboration and promotes their creativity as a specialised competence (Shanta, 2022).

By implication, technology and engineering emerge as crucial for achieving authenticity in STEM education. Technology and engineering education therefore need more educational resources so that they can inform and provide a ground for authentic STEM education, specifically through real-world modelling practices. Furthermore, it is imperative to increase awareness of engineering education because many of the participants discussed engineering design and engineering problems without realizing that they are in fact real engineering or technology problems. Finally, the STEM expert panel viewed technology and engineering as providing authentic contexts that act as bridges between school and real-world settings, which means that in order to increase authenticity in schools generally subjects would need to be infused with engineering and technology design problems. This primarily concerns the two other STEM disciplines mathematics and science but could also be in other school subjects such as geography, social studies, history, or home economics. In building upon the findings communicated in this paper, future work shall continue to obtain a wider range of international opinions to shed more light on authenticity for integrated STEM education.

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