Chapter 8
Authenticity in Extra-curricular Mathematics Activities: Researching Authenticity as a Social Construct

Pauline Vos

Abstract In this chapter I study authentic aspects in mathematics education, in particular with respect to mathematical modelling. I define 'authenticity' as a social construct, building on the French sociologist Émile Durkheim. For an aspect to be authentic, it needs to have: (1) an out-of-school origin and (2) a certification of originality. The study validates this definition, asking: what authentic aspects can be identified within mathematics education? Data were collected from the excursion *Railway Timetable Dynamics*. During the excursion secondary school students were exposed to research carried out by university mathematicians on behalf of the National Railway Company. The authentic aspects were mathematical or non-mathematical. Often the certification was a testimony by an expert.

8.1 Introduction

In mathematics education, we encounter tasks in which mathematics is connected to the real world. Many of these tasks are *word problems*, in which mathematical exercises are 'dressed-up' (Blum and Niss 1991) into a story that contextualizes the mathematics. For example, the division exercise $3\frac{1}{2} \div \frac{1}{4} = \ldots$ may be concealed in a pizza situation: *How many quarter pizza slices can you get out of three and a half pizzas?* Or the same division may be concealed in a money situation: *How many quarter dollars ($0.25) make $3.50 ?*

Generally, in word problems the degree of reality is far fetched: the problems are completely inauthentic. In the above described word problems the division activity remains isolated and the answer is a number and not a solution to a problem in real life. The only need to carry out the division is pedagogical: to do a division of

P. Vos (✉)
Department of Mathematical Sciences, University of Agder, Gimlemoen 25, Kristiansand S 4630, Norway
e-mail: fpvos@hotmail.com

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fractions. When set into a pizza situation or a money situation, the task may offer learners an idea of how division is useful in out-of-school situations, but research on adult consumers' calculations has shown that school skills are poorly applied in real life situations (Lave 1988). The lack of a link from mathematical word problems to genuine out-of-school life has been criticized (e.g., Boaler 1993; Gerofsky 1996; Verschaffel et al. 2000), pointing at problems such as: word problems ask for skills that are hardly ever needed in real life (e.g., finding the numbers concealed in a text and applying the right operation on these numbers), word problems do not offer students a real experience of the usefulness of mathematics and word problems are not appreciated by students either. Therefore, it remains a challenge of how authentic out-of-school aspects can be integrated into learning environments. In a previous study, I have problematized authenticity (Vos 2011). In this chapter, I will define *authenticity* and study the operationalization and validation of this definition.

8.2 Theoretical Background

8.2.1 Authenticity as Simulation or Imitation

In defining *authenticity,* a number of researchers have put up lists of components. For example, Heck (2010) refers to *authentic student research projects* if: (1) students work on self-selected, challenging, messy, ill-defined, open-ended problems rooted in a real life situation; (2) students do not follow some standard recipes, but examine their problem from different perspectives, using a variety of resources and high-order skills; (3) a broad range of competencies is required to make the project a success, and one of these abilities is making use of ICT for information gathering, data processing and reporting; (4) students' work is open-ended in the sense that there are multiple methods to obtain possible or even competing answers; (5) it offers students the opportunity to be in contact with contemporary, cross-disciplinary research and to learn about the nature of mathematics and science; and (6) students disclose their own understanding through a portfolio, a report or a presentation (Heck 2010, p. 116). Palm (2002, 2007) analyzes authenticity as the extent to which a task simulates a real-life performance. He offers a list to analyze tasks according to: the aspects of the event (might the event occur in real life?), the question (might the question be posed in that event?), the purpose, the information/data (are the data corresponding to real life data?), the presentation, the solution strategies, the circumstances, and the solution requirements.

In the above cases, the researchers designed activities that *imitate* or *simulate* real world activities. However, imitations and simulations are *copies*. The lists of criteria make the imitations or simulations to be near perfect copies of out-of-school activities, but the fact remains: copies are different from the real thing! In the study by Heck (2010) on the modelling of bungee jumping, students experiment with a Barbie doll in the gym, and not with real-life bungee-jumping, where a calculation error may cause death. In the study by Palm (2002, 2007), students work on a task to organize a school excursion. However, they fill in an order form from a fictitious bus company and after the number of necessary buses is filled in, the task ends and there is not a real excursion. So, while these tasks may meet a certain set of criteria set by the researchers, the tasks are still essentially inauthentic because they only *simulate* or *imitate* real life. This fact complicates the definition of authenticity in education, in particular in mathematical modelling education.

8.2.2 Authenticity as a Social Construct

According to dictionary definitions (e.g., Webster's), authenticity means that an object is authentic if it has a true origin and hasn't been copied (or forged). The term is illustrated through the discipline of Archaeology, where found artifacts are considered authentic when they truthfully originate from human activities in the past. The word *authentic* is used as a contrast to 'being a copy', such as imitations and forgeries. The qualification of being authentic is dichotomous: an artifact is either authentic or not; there is no artifact that is 'more or less authentic' or 'more authentic' than another. It is possible that an artifact receives the tag: 'authenticity cannot be established', but this un-decidedness does not render the artifact 'more or less authentic'. To establish authenticity, archaeologists have a number of methods to justify the authenticity (e.g., similarity to other authentic artifacts, the site of finding, the route that the object has travelled from the origin to its present location). In Archaeology, only acknowledged experts can give an artifact the classification of authenticity; if an outsider finds a Roman coin in his/her backyard, she/he will need to consult an expert before the artifact can be confirmed as authentic.

In this exemplary discipline of Archeology, we see that the term *authenticity* is defined in an interplay between objects and actors. The objects are (1) an artifact, that is: the object of study that is to be qualified as 'authentic' or not; (2) an origin, that is: a reality that has produced the object. The actors are: (3) the experts who decide on the qualification of authenticity; and (4) the outsiders who observe the artifact and trust the expert's authority.

The sociological analysis of the use of the term authenticity in disciplines such as Archaeology, Law and Art, shows us that authenticity is a *social construct*: it is an agreement reached through a social process. Social constructs were first studied by the French sociologist Émile Durkheim (Berger and Luckmann 1966). He studied the common language and knowledge of a community. Social constructs are, for example, 'money value', 'democracy', or 'science'. Generally, social constructs become institutionalized and they are not negotiable by individuals. Thus, a Roman coin found in someone's backyard will not be taken as authentic until an institutionalized procedure has been applied, that is until an expert has confirmed its originality, eventually with a counter-expertise.

Considering authenticity as a social construct, for an aspect in mathematics education to be considered as authentic it requires:

1. an out-of-school origin
2. a certification.

These requirements align with the definition of authenticity by Niss (1992, cited in Palm 2002, p. I-20): "We define an authentic extra-mathematical situation as one which is embedded in a true existing practice or subject area outside mathematics, and which deals with objects, phenomena, issues, or problems that are genuine to that area and recognized as such by people working in it." In this definition, the given situation has a true origin and this origin is attested to by experts. My definition of authenticity as a social construct is wider: (1) the origin can be mathematical, as long as it is from out-of-school, and (2) a certification can also be offered by other experts than "people working in it", such as stakeholders linked to other problems than workplace problems, such as consumer or environmental problems.

The study described in this chapter will validate the above definition by scrutinizing a series of mathematics activities on the presence of authentic aspects and whether the authenticity can be related to an origin and a certification. The research question is: *what authentic aspects can be identified within mathematics education*, and in particular: are authentic aspects always related to non-mathematical objects or can they also be mathematical?

8.3 Methods

For this study I observed systematically a series of mathematics activities on the presence of authentic aspects. The mathematical activities were part of a school excursion for mathematics. I selected an excursion instead of standard classroom activities, because I assumed to identify (1) more authentic aspects and (2) clear authentic aspects in extra-curricular, out-of-school mathematics activities than in regular mathematics classes. The selected excursion is one out of a collection of excursions that are organised by *ITS Academy*, a project in which four tertiary institutions in the city of Amsterdam collaborate with secondary schools (see www.ITSAcademy.nl). The goal is to motivate secondary school students for STEM studies (science, technology, engineering and mathematics) by organising motivating experiences for senior secondary school students (grades 10, 11 and 12). Many activities are organised within the schools, for example university researchers come to the schools to deliver guest lectures. Also, laboratory equipment can be borrowed by schools, and there are video lectures and on-line applications to demonstrate the work of researchers in schools. There are also excursions that take the students out of their school environment. For the natural sciences, the excursions are focused around the university's laboratory equipment that schools cannot afford. To raise more interest for Astronomy, there is an excursion to the university's telescope. For mathematics there are several excursions, for example on the modelling in Biodiversity (dynamic systems) and in Business Studies (the Black-Scholes-formula for investments). The study presented in this chapter focuses on the excursion *Railway Timetable Dynamics*, in which Graph Theory is used to model the routing of passenger trains. In this excursion, the students physically visit *Science Park,* the campus of University of Amsterdam where the Faculty of Science and Mathematics can be found.

The excursion was studied by two independent coders on aspects that could be coded as authentic: the author and a research colleague. The coders familiarised themselves with the setting of the excursion, the sequence of activities, and in the spring of 2012 they joined visits by groups of secondary school students from two secondary schools. Students' activities were videotaped, the accompanying teachers and three randomly selected students were interviewed. Thereafter, the coders created a table, listing authentic aspects; for each authentic aspect they applied the criteria for authenticity (origin and certification), so they noted a true non-educational origin and the way the justification was offered to the students. Comparing between coders, it was noted that their observations overlapped largely, albeit differing in wording. Not all aspects were observed by both coders, but they reached consensus.

8.4 Results

In the excursion described here, *Railway Timetable Dynamics*, the physical environment of the excursions was the first authentic aspect. The university premises with professors, researchers and university students, and with university halls and laboratories were all authentic. The buildings and all people present were *real*. Clearly, the secondary school students were not taken to a theatre, in which a play was performed by actors. The physical presence at the university scenes, being able to see and speak with researchers and sit in university lecture halls served to certify the authenticity of these aspects.

In the excursion *Railway Timetable Dynamics* the students are introduced to a problem from mathematical Graph Theory. In 2007 a new railway timetable was introduced by the National Dutch Railway Company (Nederlandse Spoorwegen, NS), based on research on bottlenecks in the timetable by Prof Alexander Schrijvers and his team. The research was carried out on behalf of the NS. In the excursion, the students meet with a NS-manager through live video conferencing. They see him against the background of the NS control room, while he explains the urge of the railway company to collaborate with research mathematicians, see Fig. 8.1. The live connection serves to certify the origins of the timetable problem of NS.

After meeting live with the NS-spokesman, the students' task is to create a timetable for the railway system in the northern part of the Province of North-Holland. This region was chosen because it is in the vicinity of Amsterdam and thus, it is a familiar region to most students. Also, this region is a peninsula and thus the graph for its railway system is mathematically not too complex, see Fig. 8.2.

The activities in the excursion are scaffolded: students are introduced to the mathematical symbols and techniques and they learn how a cyclic timetable is repeated every hour. Deliberately, the start of the activities is kept simple, so that

Fig. 8.1 Live video conferencing with the railway control room

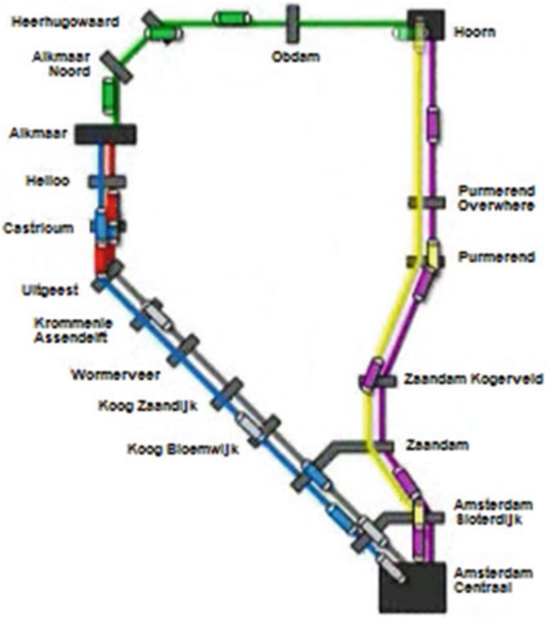

Fig. 8.2 Picture from the task in the excursion *Railway Timetable Dynamics*

all students can step in, even if they are somewhat weaker in mathematics. They start to formulate assumptions that need to be included into the model, such as the limitations caused by faster trains that do not stop at all stations, the maximal waiting time for a train (e.g., if a train waits for 20 min at a platform, this will cause passenger dissatisfaction), the transit time for passengers, and the safety distance between

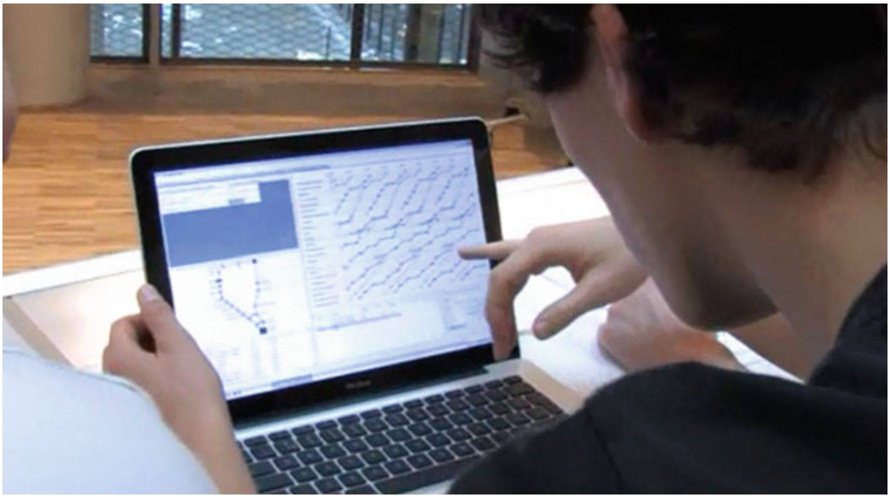

Fig. 8.3 Students working with the modelling software for the excursion *Railway Timetable Dynamics*

departing and arriving trains. After lunch, the students used modelling software to build their own timetable, see Fig. 8.3. This software was specially created for the excursion and simulates the software that the mathematical researchers used originally. It is explained to the students, that constructing software was part of the mathematicians' job when working on the bottle-necks in the NS timetable.

The original problem, to create a new timetable, was observed as authentic, as it originated from the NS and it was certified in the live video conferencing. This live connection turned out to be pivotal in convincing students that the mathematical activities really served to solve practical problems. However, the problem given to the students to find a timetable for the province of North Holland was observed as inauthentic, because it was a reduced problem for pedagogical reasons and the students merely simulated the researchers' work. The original work was far more complex and could not be covered in the time span of the excursion. Also, students did not need to report back solutions to the NS in such a way that their solution would be implemented. If they made errors, it did not have consequences for the company nor for the passengers. Also, the software used was inauthentic, as well as the 'research experience' (the excursion simulated the work of research mathematicians; the students only worked for a few hours on one problem, not for weeks or longer, not under time pressure). However, an authentic aspect in this excursion was the 'researcher's frustration', that is: students worked for a long time on one single problem without finding a reasonable solution, and thereby discovering that the problem was far more complex than anticipated. The authenticity of this experience was certified by the university researcher who recounted his own frustrations and his need for perseverance while doing research.

Another authentic aspect found was the applicability of mathematics, that is: the excursion showed the students how real mathematics researchers use mathematics to improve real timetabling problems of railway companies. This was certified by the expert in the video-conferencing meeting.

8.5 Conclusion and Discussion

In this small-scale study we can observe a range of authentic aspects in mathematical modelling education. The authentic aspects can be distinguished as mathematical or non-mathematical. Observed authentic aspects that are within the field of mathematics: authentic symbols (identical to the ones used by the researchers), authentic research questions (to resolve the bottlenecks in the railway timetable), authentic research experiences (working for a long time and not finding an answer). As non-mathematical aspects, we observed authentic buildings, authentic professionals, authentic applicability of mathematics to authentic problems (graph theory and its applicability to the railway company's timetable problem) and authentic problem settings (stations, platforms, waiting time for passengers).

In this excursion, *Railway Timetable Dynamics*, we also observed the reduction of authentic aspects into inauthentic aspects: we observed how activities from the real world were downsized, simplified and reduced to match the educational setting, which is framed by time constraints and limited skills of the participants. This reduction serves the educational purposes, which were: to offer students experiences and give them a 'feel' of what real professionals do with real mathematics in the real world. Within the learning environment for modelling education not everything can or needs to be authentic. There are so many different aspects within a learning environment, such as goals, resources, media, activities and so forth, that it is unnecessary to have all aspects be authentic. If all aspects of a learning environment would be authentic, the students would take up the full task of a professional. This would mean that mathematical errors would have serious consequences, such as errors in the railway timetable or loss of money for the company.

The extra-curricular experience for students offers an epistemological insight into the learning of mathematics. Often, we discern in the learning of mathematics different strands needed for becoming mathematically proficient, such as: conceptual knowledge, procedural fluency, strategic problem solving competencies, and so forth. The present study demonstrates the necessity for students to construct knowledge *about* mathematics, in particular knowledge about the utility of mathematics (e.g., for solving complex timetable problems). This knowledge may be attained without fully understanding the underlying mathematical concepts or procedures. Whether this knowledge affects students' mathematical disposition is a point for further studies.

In this present study, authenticity is strongly related to the work of professional mathematical researchers. Of course, this is due to the object of study: an excursion to a university will mirror the work of university mathematicians. If the focus had been on the modelling of consumer activities, the authentic aspects would relate to consumer aspects.

Taking authenticity as a social construct, we verified whether each aspect had an out-of-school origin and whether this origin could be certified. Often the certification consisted of a testimony by an expert, in particular the video conferencing with the NS control room played a pivotal role in the certification. We noted that for a number of authentic aspects the origins and certifications were not always explicitly given, while this could have been done. For example, the symbols used in the mathematical model were authentic, being the original symbols that the university researchers had introduced in their research process. However, this fact was not made explicit and the students complained of the symbols' awkwardness. Probably the excursion trainers were not aware of the importance of the certification, and the visiting students did not ask. Here, we obviously see points for improvement in the design of learning environments.

In this chapter I defined authenticity as a social construct, whereby each authentic aspect has an out-of-school origin and a certification of this. This definition was practical for separate aspects in a learning environment. This definition differs from those definitions with lists of criteria, in which cause and effect are reversed. When a modelling activity contains authentic aspects, this causes the activity to be fuzzy, open-ended, requiring higher-order thinking and so forth. It means that the lists of features offered by a number of authors (e.g., Heck 2010; Palm 2002, 2007) are *implications* of authentic aspects and not *indicators* or *descriptors* of authenticity.

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