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To double a recipe – interdisciplinary teaching and learning of mathematical content knowledge in a home economics setting

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Abstract

This study examines if interdisciplinary teaching can be said to facilitate the learning and use of fractions by Swedish 12-year-old pupils. Home and Consumer Studies is well suited to interdisciplinary teaching, and young people can therefore find it interesting to study maths since the setting is relevant to them. Building on variation theory and a learning study, we examined pupils' (n = 18) ability to double fractions greater than ½ when using a recipe. The general results show that what is to be learned benefits if it is presented in different ways, that teachers should not take pupils' knowledge for granted, and mathematically that it is not necessary to divide something to be able to double it. We argue that the study shows that genuine problems based on pupils' interest and life world can enhance motivation and, in turn, learning.

Keywords: Home and Consumer Studies, interdisciplinary teaching, variation theory, learning study, mathematics

Mathematics is a school subject which contributes to Home and Consumer Studies (HCS). Using knowledge from mathematics classes in real kitchen situations should be no problem since the same comprehension is necessary when fractions, for example, are in focus. Regardless of the situation, 3/4 as a fraction is separated from its representation, it is 3/4 whatever we are counting – spoons, kilograms or carrots – and whether we do it in theory or in practice. Pupils who have learned to use fractions in mathematics should not have any difficulty transferring this knowledge when they come upon fractions in a recipe in HCS; namely, "what is learned in one situation affects or influences what the learner is capable of doing in another situation" (Marton 2006, 499). However, this is only true if the learner has separated the principle of 3/4 from its representations.

Home and Consumer Studies is a school subject with great interdisciplinary possibilities because it can encompass many different school subjects within its

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margins. Something similar was highlighted by Dewey (1998) who expressed a belief in the importance of continuity and lived experience since the process and the goal of education are the same. Linking different school subjects in practical, everyday exercises can therefore be fruitful. A cinnamon roll, for example, is a pastry made out of yeast, flour, sugar, butter, eggs and cinnamon. However, within HCS a cinnamon roll can also be the focus of a study concerning the biology of yeast (biology); a description of transportation routes to bring cinnamon to the Western world (geography, social science); a consideration of expenses and costs (mathematics, economics) and nutritional values (health); a critical examination of the living conditions of hens (ethics); and calculations regarding raw materials (sustainable development) and supply and demand (business economics) when selling the pastry (economics). However one views it, HCS holds great interdisciplinary potential. Researchers (Dewey 1997; Osborne and Dillon 2008) point out the importance of basing teaching on young people's interests and lives. Thus, we take a position in association with Dewey (1997; 1998) and submit that it is children's own lives that should be the basis for learning and not construed necessities like various subjects with watertight bulkheads between them. This is also in line with the Swedish curricula which states that all teaching should be based on pupils' prior experiences and background (National Agency of Education 2011). Many pupils think that HCS is interesting and a majority enjoy the subject (National Agency of Education 2003), which could be an incentive to learn other things, like mathematics.

In this study, we use the learning study model (Holmqvist, Gustavsson and Wernberg 2008) as a method to gather data about 12-year-old pupils' understanding and use of fractions while they create a smoothie in HCS – that is, in an interdisciplinary setting combining more than one school subject. As pupils of this age in Sweden should have knowledge about fractions (National Agency of Education 2011), it was useful to examine whether and to what degree pupils in school year 6 can use their mathematical knowledge in HCS. The aim of the article is to discuss if and how interdisciplinary teaching can be said to facilitate pupils' learning. This is done with the help of variation theory as a theoretical base; the subject used is mathematics in an HCS setting.

HCS as a school subject

The Swedish curriculum for HCS has three general areas of focus: *food, meals and health*; *lifestyle and environment*; and *consumption and personal finances*. Here we focus on food and meals, that is, how to use different preparation methods, recipes, raw materials, and kitchen tools. In lower grades of comprehensive school in Sweden the teaching focus is on how to read recipes and how to follow recipes to create simple meals (National Agency of Education 2011). Low cooking skills have been associated with a "lack [of] the ability and opportunity to control the diet with ease and follow healthy eating principles" (Short 2003, 177). The risk of low nutritional values among the population, as well as to compel women to supply their husbands with food, was the reason for providing nutrition education in schools (Hirdman 1983; Hjälmeskog 2000).

In HCS pupils can take knowledge from different school subjects and apply it in practical, real-life situations. Some of the common textbooks on HCS in Sweden (e.g., Algotson and Eriksson 2003; Hedelin et al. 2009) make considerable use of mathematics. For example, there are diagrams of nutritional values of different groceries, mathematical formulas to estimate energy (kcal and kJ), exercises for comparing prices and calculating household budgets, and the use of fractions in recipes. Besides mathematics, other traditional school subjects are commonly combined with HCS, including science, geography, religion and, of course, language.

Theoretical framework

This study is based on interdisciplinary teaching. However, we also used the theory of variation (Marton and Booth 1997; Runesson 1999) as a point of departure for the theoretical thinking about learning as such, and we used a learning study (Holmqvist et al. 2008; Marton and Tsui 2004) as a method for data sampling.

Interdisciplinary teaching and learning

As pointed out above, HCS can be said to encompass the contents of several school subjects. Interdisciplinarity is often defined as the combining of disciplines (Lattuca, Voigt and Fath 2004; Rooks and Winkler 2012; Yang 2009), but also as an integrated phenomenon (Campbell and Henning 2010; Spelt et al. 2009), which at least sometimes is accomplished through team teaching by teachers from different disciplines (Yang 2009). Lattuca, Voigt and Fath (2004) discuss four types of interdisciplinary teaching with different characteristics. These differences are due to the content and design of an educational situation. Our project can be said to be the most modest form of interdisciplinarity, called *informed disciplinarity*, a type which primarily focuses on one subject but uses other disciplines to clarify and explain any problems that arise. We introduce the pupils with a doubling of fractions while making smoothies in an HCS environment. The pupils have to use and understand mathematics if they want their smoothies to taste right. This is one way to accomplish interdisciplinary teaching. In this study, we use maths in an HCS context, this is not something spectacular as is done every day in HCS. However, here it is consciously implemented and we also examine the result of doing this via a learning study. Further, what interests us is the learning of fractions, and not the taste of the smoothie. Further, it is the teacher of HCS who teaches the pupils about mathematics while talking about how to prepare a smoothie.

Campbell and Henning (2010, 180) argue that the need for interdisciplinary learning (and teaching, our point) is based on the consensus that “knowledge is becoming increasingly interdisciplinary”. In a similar way it is possible to maintain, as Rooks and Winkler (2012, 3) do, that interdisciplinary work is based on the fact that certain questions cannot be answered without reference to disciplines or cultures other than one's own, and that the result is that "students learn that knowledge is not compartmentalized and that in the real world, knowledge is transferable and cumulative". Dewey (1997) discusses in terms of development based on continuity and interaction; it is inevitable as we live in and are constantly influenced by the surrounding society. Yang (2009, 300) points out that for something to be called interdisciplinary the teachers involved must regard the subjects included as "interacting means of dealing with a human problem or activity", and they must be willing to learn from other disciplines, foremost to understand their theoretical viewpoints and how they are applied. Acting in such a way signifies teaching in context, but it also suggests that the content and design of other subjects are treated seriously by all included.

The advantage of the interdisciplinary nature of HCS is not so much that it incorporates multiple subjects but, and this is especially important for young people, that the subjects are presented in a way that is meaningful to them and applicable in their daily lives (cf. Dewey 1998). It is possible to employ interdisciplinary, thematic or multi-disciplinary teaching, with cooperating teachers from different subjects, to place subjects that pupils find less interesting (Osborne and Dillon 2008) into contexts that are more interesting and relevant to them. Runesson and Mok (2004) refer to the postman's route as a basis to develop problem-solving, creativity and divergent thinking among pupils. This can be a pragmatic and combined effect of interdisciplinary teaching and learning, and is something we see as a feature of HCS.

Variation Theory

According to variation theory (VT), "Learning is always directed at something (phenomenon, object, skills, or certain aspects of reality) and . . . learning must result in a qualitative change in the way of seeing this 'something' . . .. This something at which learning is directed is called the object of learning" (Lo and Marton 2012, 9). In this study, the object of learning is the doubling of fractions used in HCS. All learning objects have different aspects according to variation theory, and some of these aspects are essential to the object; a cinnamon roll, for instance, needs cinnamon seasoning to be a cinnamon roll, and the doubling of fractions needs a focus on the size of the denominator. According to variation theory, aspects that are not discerned and comprehended in a certain object of learning are regarded as critical aspects of learning, such as when someone has not experienced the difference between cinnamon and cardamom and so cannot distinguish between the taste of a cinnamon roll and a cardamom roll. Such a person can taste the difference but cannot point out which of the rolls is flavoured with cinnamon. To experience a certain object of learning it is necessary to discern the different aspects of that object, and when all the different aspects have been experienced it is possible to discern the similarities and differences between the object of learning and other objects of learning. Variations of the object of learning should be discerned simultaneously. To be able to discern an object, one has to separate or understand the variance of the object, often through different values (Lo and Marton 2012). Hence, the variance in the rolls is illustrated through the flavouring. If nothing is invariant, the discerning will be difficult. To be able to understand which aspects are critical for pupils within an object of learning, teachers must analyse what pupils do not recognise or comprehend because pupils may focus on aspects not required to understand the object of learning, or not see all of its aspects simultaneously (Lo and Marton 2012). In the study, we had some difficulties concerning the variation such as, for instance, that 3/4 of a leek is something else than 3/4 of milk. We also found during the study that one word (double) which we had assumed the pupils knew was probably not known by all of them. By identifying different patterns of variation, it is possible to acquire tools to consciously examine what is variant and invariant regarding a certain object of learning, and it is thereby possible to understand what is and what is not possible to learn in a certain situation.

Learning Study

The core of a learning study is the cooperation of teachers and researchers on refining how the object of learning should be composed and presented to the pupils. All learning studies start with discussions between teachers and researchers concerning the possible aspects of the object of learning intended to be taught. A learning study can be viewed as an experiment accomplished through an action research situation (Elliott 2009; Noffke 2009). Relations between thoughts about practice (chiefly researchers) and acting in practice (chiefly teachers) are thereby created and used in a learning study (Elliott 2009; Holmqvist, Brante and Tullgren 2012).

The collaboration between teachers and researchers results in the design of a test that is applied throughout the study. This test is used before an intervention (*pre-test*), directly after the intervention (*post-test*), and sometimes about eight weeks after the intervention (*delayed post-test*). This is called a learning study cycle, and these are repeated a number of times in a learning study with different, but comparable learners each time. The test is the same, or very similar, every time in a particular learning study to be able to compare the outcome between the interventions. Important results of these tests are the differences between the pre- and post-tests as they can show if the intervention actually changed the pupils' knowledge or understanding (it could be considered strange if no change is reported in the post-test). This first collaboration between teachers and researchers also results in the planning of the first intervention plan. This intervention plan is detailed, and concerns which aspects of the object of learning should be discussed and made discernible during the first lesson (see *The first lesson*, p. 10 f and *The second lesson*, p. 11 f for the detailed intervention plans for this study).

The goal of a learning study is to enable teachers to understand and discern how teaching can be thought about and designed to create situations for learning. The focus is on *what* pupils are learning in relation to a certain object of learning, and not on *how* they learn. Learning studies are primarily used to enhance pupils' learning by helping teachers discern and learn how a theoretical perspective (variation theory) helps better understand some of the complex and problematic aspects of learning situations, like for instance that how teachers present, talk about and act on an object of learning creates different possibilities for the learners to learn that object of learning. Lo and Marton (2012, 8) state that "the focus of the [learning] study is on helping teachers to help pupils learn the object of learning".

In this learning study, we only used two cycles due to a shortage of pupils. Each cycle meets a different group of learners. To be able to draw any conclusions from a learning study, it is important that the different groups of learners be similar in composition; this is achieved by dividing a large group of learners (for instance two school classes) into, for example, three groups with a similar composition in terms of their levels of knowledge about the object of learning (Holmqvist et al. 2007). In this study, we divided one school class into two groups. A *screening test* can initially be used to try to find out what the critical aspects of the object of learning are for the examined group, as well as which of the learners are strong and which are weaker in terms of their grasp of the subject to be examined in the learning study. We carried out a screening test on the pupils who later participated in the study.

After the first cycle, teachers and researchers analyse the results of the pre- and post-tests (the lived object of learning) and discuss what was intended and enacted during the lesson. They thereby decide what should be changed regarding how the object of learning is presented, with the intention to improve the lesson design. This will give the next group of pupils a better opportunity to discern the object of learning. Then the second cycle starts with the same pre-test, the somewhat changed intervention and the same post-test.

Fractions as a school subject

Fractions are considered to be very difficult to master (Courey et al. 2012; Kullberg and Runesson, accepted for publication); however, if fractions can be combined and explained in connection to real-world contexts (Li, Chen and An 2009), for instance through music instruction as proposed by Courey et al. (2012) or HCS as in this article, it can be easier to discern its aspects. Li, Chen and Kulm (2009) discuss the value of lesson planning in accordance with fractions, and found not only that planning still can be measured as a means to achieve high-quality lessons, but also that it enhances teachers' own understanding of content, thinking and crafting instructional methods and by this "help to lead high-quality classroom instruction" (730). The learning study method can be seen as a way of thinking about and training lesson planning, and to realise that different ways of expressing and offering the object of learning will lead to different possibilities to discern and understand that object.

In the past, fractions were commonly used in everyday mathematical calculations, for example in the course of food distribution, commercial trade and agricultural activities (Kilborn 1999; Streetland 1991). Since the decimal number system became generally accepted, decimals have gradually replaced fractions in arithmetic. This can be seen as a more difficult way for pupils as this involves a change from an everyday thinking to a formal mathematical thinking (Kilborn 1999). According to Löwing (2006), the use of fractions in Swedish comprehensive schools has declined – possibly because of the reduced use of fractions in everyday life, but perhaps also because fractions are considered difficult – and because many teachers avoid fractions and instead let pupils work with the decimal system. Löwing and Kilborn (2002) point out that teachers do not seem aware that decimal numbers represent a specific way to transcribe fractions, and that the rules for decimal numbers derive from fractions.

It is in practical situations, such as in music instruction (Courey et al. 2012) or when actually tasting the smoothie, that the theoretical knowledge of fractions is tested in practice. A smoothie will be different if 3–4 tablespoons of vanilla extract are used to make it instead of 3/4 of a tablespoon. Fractions concern the mutual relation between parts and wholes. The fraction 1/4 consists of the part where one (1) is a number of quarters, and where the whole consists of four (4) quarters. Many pupils have difficulty understanding the relation between parts and wholes (Holmqvist, Tullgren and Brante 2012; Kullberg 2010; Lamon 1999). An understanding of fractions is important as such understanding can be seen as a prerequisite for understanding other mathematical fields, such as algebra and geometry and for grasping the concept of infinity (Kilborn 1999; Runesson 1999). The Swedish curricula for school years 4–6 (National Agency of Education 2011) state that the pupils should have fundamental knowledge about numbers.

In this study, we investigate if different lessons dealing with the preparation of a 'smoothie' in which doubling of the fraction is a prominent part can be said to change students' understanding of fractions and the use of doubling the fraction. In this way, we mean that we use an interdisciplinary approach, and that we simultaneously base the investigation on a theory of learning (VT) and use a certain method (learning study) to gather the data.

Method

The goal of the study was to teach pupils (n = 18) to double fractions. This was examined through pupils' understandings of a mathematical object of learning (doubling of fractions greater than ½) within a home and consumer context (the preparation of a smoothie), and whether the pupils' understandings of doubling fractions changed after an intervention consisting of instructions for the smoothie's preparation (mathematics in an HCS context). The intervention is viewed as an informed interdisciplinarity, that is, we use the mixing of a smoothie within an HCS setting to teach the pupils how to double fractions. We use Maxwell's (2002) definition of "validity as understanding", which suggests that it is possible to interpret the world in different ways, and that different interpretations of dissimilar phenomena can be valid. Without taking a relative position, it is necessary to consider the utterances of diverse respondents and discuss the ways in which their expressions can be seen as plausible, adequate and understandable. This is of course applicable to both the participating teacher and the researchers. As interpreters, we have memories and understandings of people's ways of talking about different phenomena, and can argue for the validity of qualitative data.

The study consists of three parts: a screening test; a pre-test and post-test conducted in two cycles (the learning study); and a mathematical test. All three parts provide us with data and have linkages with each other (see Table 1).

The screening test

The pupils took a *screening test* to gauge their understanding of fractions in HCS. The questions concerned fractions in different variations, and most of them required answers in the form of drawings. In the screening, the different possible aspects

Table 1. The three parts of the study and their different objectives

	Screening test	Pre- and post-test Cycle 1	Cycle 2	Mathematical test
What?	Questions about fractions and doubling	To double 3/4 of an apple; this is done twice in a pre- and a post-test, with an intervention in-between	To double 3,4 of an apple; this is done twice in a pre- and a post-test, with an intervention in-between	To do a standard mathematical test on fractions
How?	Answer by drawing and writing text	Hands-on approach using apples and a knife to illustrate the doubling of 3/4	Hands-on approach using apples and a knife to illustrate the doubling of 3/4	A standard mathematical test
Who?	All the pupils at the same time	One pupil at a time together with a researcher; half of the group in cycle one	One pupil at a time together with a researcher; half of the group in cycle one	All the pupils at the same time
Use of the result?	Basis for dividing the pupils into groups as similar as possible concerning the knowledge shown about fractions	Analysing the difference in results between the pre- and post-test for each individual pupil	Analysing the difference in results between the pre- and post-test for each individual pupil	Comparing the result with pupils' hands-on accomplishments

of the object of learning were offered in different variant and invariant forms. The test ended with an assignment to double a recipe containing an unusually high number of fractions. In this test, the pupils had considerable difficulty dealing with fractions greater than 1/2 and with mixed fractions, for instance, adding sums such as 2 2/3 + 2 2/3 = 5 1/3. Thus, since adding fractions greater than 1/2 seemed to be a critical aspect for the pupils, it was decided to make that the object of learning in the study. One of the questions in the screening did not focus on fractions, namely "What is a recipe?". We had to be sure that the pupils knew what a recipe was as it otherwise could be a weak understanding of recipe which might impair their results on fractions. Most pupils knew what a recipe was, although some did not.

A group constellation was made from the results in the screening. Two categories of pupils were established with regard to their accomplishment in the screening test: those who passed the test with no or few errors, and those who passed the test less well. Accordingly, two groups were created, as similar as possible in terms of how they had managed the screening, that is, both groups were comparable concerning the number of pupils with no or few errors and pupils who had passed the test less well. This enabled comparisons to be made between the groups. These groups consisted of nine pupils each, and were the groups that participated in the study.

The study

The objective was to see whether and how an intervention can change pupils' comprehension of a certain object of learning. In this study, this is shown in a real-life situation (the making of a smoothie to drink) completed within an interdisciplinary situation (using maths in an HCS context). We use the making of a smoothie, a drink we imagine the pupils like and want to have, to teach the doubling of fractions. Learning is considered to be a change in how the learner experiences a phenomenon (Marton & Booth, 1997). Thus, the important factor in a research situation involving learning is whether something changed between the pupils' pre- and post-tests, not primarily whether the pupils' answers were right or wrong; in this way, change is analysable. Whether and how the pupils change their view of the object of learning can give an insight into the impact the intervention had on them. On the other hand, a pupil who knows how to add fractions is not supposed to change their views on the object of learning in this study. The data presentation is differentiated according to the changes in the ability to conduct the doubling of 3/4 of an apple that the pupils show between the pre- and post-tests. As data for the analysis, we have video-recordings from the interventions, the pre- and post-test interviews, and the results of the pre- and post-tests. The interpretation considers both what the pupils said and what they did in the tests. What was focused on in the analysis of the pre- and post-tests was whether the pupils understood the meaning of quarters, that quarters are four parts of the same size and not just four parts, and whether they were able to double fractions greater than 1/2 after the intervention.

The pre- and post-tests were the same throughout the cycle. All tests were composed of one question: "If a recipe says that you should take 3/4 of an apple and then double it, how much is it?". In the tests, which were video-recorded, each pupil sat at a table with the interviewer. In front of them were a knife, a cutting board, and a bowl with apples of a similar size. The pupil could use as many apples as they wanted. The interviewer talked with the pupil while they completed the test, allowing us to analyse the level of understanding and use of the doubling of fractions. Each pupil was subjected to two tests where they were supposed to double 3/4 of an apple. This was done precisely before and after the intervention. Therefore, the difference between the results in the pre- and post-test must be a function of what was done in the intervention.

The two lessons (L1 and L2), or interventions, consisted of two parts, one theoretical and one practical. The lessons were similar in design; first, there was a theoretical description and definition of the concepts and aspects used, and then a practical setting where the pupils were to create a yoghurt-based drink called a smoothie. This was done with the intention to vary the critical aspects and to make them discernible for the pupils, and thus for them to be able to do it correctly while making the smoothie.

The first lesson

During the first lesson, the teacher talked about fractions and held the fraction 3/4 invariant. She said that 4/4 was the same as a whole, and explained that 3/4 + 3/4 are the same as 6/4, or 1 1/2, and that it is only the numerator that changes when doubling fractions. Then she poured a pre-measured quantity of 6/4 cups of water into a decilitre-unit container. She did this over a bowl to catch the surplus water. Then she measured the water in the bowl, and the pupils could see that it was 1/2 a cup. She then repeated this with sugar. After this, the pupils were given a smoothie recipe for one serving and were instructed to make enough for two servings; consequently, they had to double all the ingredients in the recipe before they started making the smoothies. They had to rely on paper and pencil, or mental mathematics, that is, it was a situation comparable to a mathematical test.

Result and discussion of the first lesson

In the pre-test before the first lesson, four (4 of 9) pupils showed an understanding of dividing an apple into quarters; in the post-test three more pupils (7 of 9) divided the apple correctly. Stimulated by the results of the first post-test, the researchers and teachers discussed that the pupils did not have an opportunity to discern and experience that quarters should consist of four parts of exactly the same size, and not just four parts. It had been mentioned during the lesson, but it could have been emphasised more explicitly. Another point that was not clearly made was that the difference should be apparent between dividing a decilitre of *liquid* substance and dividing a *solid* object such as a fruit. Finally, it was not necessarily clear for the pupils why 3/4 was in focus.

The second lesson

L2 was conducted by the same teacher who did L1, but with a somewhat different discussion in the theoretical part of the lesson, built on the analysis after the first lesson. The teacher started by stressing why 3/4 was in focus, saying it was because it is an amount commonly found in recipes. If you do not understand 3/4, what you cook might not taste the way you expect it to. Therefore, the pupils were going to use 3/4 when making smoothies during the lesson. Then the teacher asked an open question about how something is when it is in quarters. One pupil suggested that she should draw a rectangle and divide it into four parts. The teacher did this and stressed that the parts should be exactly the same size. Then she talked about doubling a fraction and emphasised that it is the numerator that changes when fractions are doubled. After that, an example with 6/4 cups of sugar was offered, but this time it was followed by the dividing of a potato. When the teacher cut the potato she stressed how complicated it is to create quarters of the same size from such a unit, but that the pieces should at least be roughly the same size. Then it was time for the pupils to double the recipes and prepare their smoothies.

Result and discussion of the second lesson

In the pre-test of the second lesson, six pupils (6 of 9) understood how to divide an apple into quarters; in the post-test, all of the pupils, even those with a poorer understanding of fractions, divided it correctly, which did not happen in the post-test of L1. This result is in line with what we predicted, and we presume that the changes and focus on certain aspects in L2 in comparison to L1 is the cause of this. For instance, the dividing up of the potato during the lesson could be one cause of this change; it led to a deeper understanding of the importance of size. The pupils understood the need to try to have the same size even if it is hard to accomplish. In the second intervention, 3/4 was also connected more consistently to the reality of the situation, namely, to home-economics textbooks, recipes in general, and to the pupils' smoothie recipe, which thereby becomes a second explicit changed focus between the two interventions. This conduct during the intervention suggests that it became vital for the pupils to comprehend the adding of fractions to produce well-tasting smoothies. It could be seen as a reason for a deeper understanding of parts and wholes, but also for the learning of doubling 3/4. Further, in line with the reasoning of Courey et al., (2012), we imagine that the home and consumer kitchen context "allowed" the pupils to find the lesson challenging and even "fun".

The mathematical test

A *mathematics test* entailing the addition of fractions was constructed in cooperation with a mathematics teacher. The pupils took this test in a mathematics lesson so that the context would be mathematical. The mathematical test was carried out three days after intervention two. The aim was to find out if the pupils could add fractions greater than 1/2 in a mathematical context, that is, if the pupils had gained a theoretical understanding of adding fractions. We found that some of them had since half of the pupils could answer questions about the doubling of fractions greater than 1/2 without any problem, and only a few had difficulties. There is no striking difference between the low achievers in the respective groups. From a general point of view, the pupils who could calculate in practice also could do so in theory.

Discussion

As three pupils in both groups changed how they experienced the object of learning in the learning study, and since no pupil showed a decline in understanding or reduced accomplishment in the post-test compared to the pre-test, we argue that the intervention was successful. The intended object of learning was the doubling of fractions greater than ½ within HCS. During the interventions and the pre- and post-tests, we had a focus on the fraction 3/4 as this was the fraction the pupils had problems with in the screening test. The analysis shows that the enacted object of learning, namely, what the object is and how the lesson was carried through, was not completely in agreement with the intended object of learning, at least not in the first lesson.

Fractions were not focused on in this study; instead, fractions functioned as an example of an object of learning within a study where we studied pupils using HCS to learn a mathematical concept. The pupils accomplished the required calculations in the interdisciplinary context with an acceptable result, but did not accomplish it as well in the mathematical context. We compared the two different settings and, as the mathematical context comes after the interdisciplinary one, it is possible to believe that it would function in a more satisfactory way. In both settings, the actual calculation is done with pen and paper, but it seems that when the calculation is done within a process (the making of a smoothie) the result is more fulfilling.

We found three phenomena linked in some way to the understanding of fractions, which may be seen as somewhat general conclusions when planning lessons. First, an object of learning can be presented in more than one way, both in connection to the singular aspects of the object of learning, and to what the object of learning is as a whole, in accordance with variation theory. In our example, it seems as if pupils who are offered a more visible representation of the critical aspects of an object of learning tend to understand it more readily. For the pupils in our example to really be able to understand the difference between quarters and four parts, we should have offered them a greater number of examples of 3/4 because pupils may well have difficulty discerning the difference between 3/4 of a quantity of milk, 3/4 of an apple, and 3/4 of a number of peas. That is, pupils should be presented with examples of different wholes and variations of wholes so that they experience carrying the concept of 3/4 over to different types of substances (Runesson and Mok 2004). It is necessary to vary the representations (of 3/4), even if the core of the object of learning (a fraction) is held invariant. Second, a phenomenon linked to learning in this study, and which was perceived as a problem, was that we had anticipated that the pupils would know the concept of doubling. This is connected to the aspect of wholes and parts, a well-known problem among pupils (Kullberg 2010), and it gives us the information that teachers must know that what they offer is known and understandable by the learner. Third, a possible phenomenon, and maybe a critical aspect when it comes to understanding fractions, is to let the pupils understand that it is not necessary to divide something to be able to double it. This is more closely connected to fractions; however, it gives the information that it is easy that pre-conceived ways and ideas can be problematic with regard to how things should be done and communicated in education. All three of these phenomena can be coupled to fractions.

Many students dislike mathematics which implies that they become unmotivated and negative regarding situations with a mathematical content. By offering them knowledge of fractions in an HCS context where the task is to learn how to produce a smoothie, we assume their resistance may decrease. The interdisciplinary situation made students more receptive to the mathematical teaching they encountered because they realised that they would otherwise end up with a less tasty smoothie. In this way, it is possible to argue for interdisciplinary teaching as a tool for making pupils more interested to learn. Second, interdisciplinary teaching also has the possibility to give a scenario a more realistic context since what is learned seems like things from real life, or you can even use real-life problems.

That something happened between the pre- and post-tests is clear because more pupils completed the post-test successfully. We may suggest that the pupils took the knowledge they had about the fraction 3/4 in mathematics and applied it in HCS. Or conversely, what the pupils learned in HCS may have helped them complete the mathematics exam. We call this 'the smoothie effect', that is, the influence of doing mathematics in a home and consumer setting, along with the importance of the pupils' task in the intervention being a genuine problem. This means that certain contexts might be better for learning as they include in a natural way concepts, phenomena and other lessons that are important for young people to learn.

Another result of this learning study, discovered during discussions with the participating teacher, is that she became conscious about the need to be aware of what the children are offered to learn as this affects what is learned. Further, that it is possible to present a certain object of learning in more ways than one, and that reflections and planning on such actions can enhance not only pupils' learning, but also teachers' teaching (Li, Chen and Klum 2009).

We argue that schoolwork would be different if school activities were more strongly based on pupils' interests and their everyday problems and experiences. Today, we hear about pupils' diminishing interest in school subjects such as physics and mathematics (Osborne and Dillon 2008). We contend that interdisciplinary teaching and HCS encompass teaching and learning that can be used in a number of other school subjects in a similar way as interdisciplinary teaching, and allow information and data to be presented to pupils in what for them are more interesting ways.

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Appendix

Instructions for Interviewer (video-taped interviews)

1. We will explain to the students that we have a recipe in which to take 3/4 of an apple, but the recipe should be doubled. Then we ask them: Can you show me how much it will be?
2. We tell the students they can use a knife, cutting boards and as many apples as they want. In front of them is a knife, a cutting board and a bowl with lots of apples that are roughly the same size.
3. While the students carry out the task we ask questions to find out what they think about what they are doing.

PRE-TEST

I: If it says in a recipe that you should use 3/4 apple, and you have to double the recipe, can you show me how you do that? You can use these apples.

Student: (cuts an apple into four quarters, putting away three and says) There are 3/4.

I: And then you should double the recipe. How much do you need?

Student: (silence).

I: Do you know what double means?

Student: Yes.

I: You have to show how much it is. Twice the amount of 3/4, how much will it be?

Student: (cuts one more apple into quarters).

I: What are your thoughts? (*Hur tänker du*?)

Student: (silence. cuts another apple, first in half so that it becomes a half, then one-half into two, saying) Ready!

I: Hmmm, how did you think? Which parts do you mean are, so to say, the answer? Is it everyone or is it these here or here?

Student: It's everyone.

I: Okay.

POST-TEST

I: If you see in a recipe that you should have 3/4 of an apple, and then you should double it ...

Student: (cuts an apple into four quarters, picking off one of the pieces. Cuts another apple in the same way, picking off one piece and puts 6 parts in a pile). Done.

I: Is it those pieces?

Student: Yes, it is six of them.

The Swedish version

1. Vi ska förklara för eleven att vi har ett recept där man ska ta 3/4 äpple, men att receptet ska dubbleras. Kan du visa mig hur mycket det blir?
2. Vi säger till dem att de får använda kniv, skärbräda och hur många äpplen de vill.
3. Under tiden eleven bearbetar uppgiften ställer vi frågor för att utröna hur de tänker kring vad de utför?

PRE-TEST

I: Om det står i ett recept att man ska ha 3/4 äpple, och så ska du dubbla det, kan du visa mig hur mycket äpple du behöver då? Du kan använda äpplena här.
Elev: Delar ett äppel i fyra fjärdedelar, plockar undan tre stycken och säger att där är 3/4

I: Och så skulle du dubbla receptet, hur mycket behöver du då?

Elev: tystnad

I: Vet du vad dubbla betyder?

Elev: Ja

I: Du får visa hur mycket det blir, dubbelt så mycket av 3/4, hur mycket blir det?

Elev: delar ytterligare ett äpple i fyra delar

I: Hur tänker du?

Elev: Tystnad. Delar ytterligare ett äpple, först på mitten så att det blir en halv, sedan en halva på två. Säger "klart!"

I: mm, hur tänkte du? Vilka menar du är så att säga svaret? Är det allihopa eller är det de här eller de här?

Elev: det är allihopa.

I: okej

POST-TEST

I: om det står i ett recept att du ska ha 3/4 äpple, och så ska du dubbla det.

Elev: delar ett äpple i fyra fjärdedelar, plockar bort en av bitarna. Skär ett äpple till på samma sätt, plockar bort en bit och lägger 6 delar i en hög. "Så"

I: Är det de bitarna?

Elev: Ja, det är ju sex stycken