Motivating Upper Secondary Students to Learn Mathematics with Working Life Exercises

Päivi Porras[1] and Johanna Naukkarinen[2]
[1]*Technology, LAB UAS, Skinnarilankatu 36, Lappeenranta, Finland*
[2]*School of Energy Systems, LUT University, Lappeenranta, Finland*

Keywords: Mathematics, STACK, Moodle, GeoGebra, Virtual Reality.

Abstract: This paper describes a massive open online course (MOOC) that targets upper secondary school students. During the years that we have been working in LUMA Centre Saimaa (an organization to inspire and motivate children and youth in mathematics, science and technology), we have noticed that upper secondary school students often fail to see the connection between mathematics studied at that level and their future career plans. This work-in-progress paper describes a construction and first user experiences of project TyöMAA, which aims at strengthening the high school students' perceptions of the applicability of mathematics in the working life. This is done by giving upper secondary school mathematics teachers real working life examples connected to topics in their courses and developing a MOOC for students in which they can solve work-related mathematical problems.

1 INTRODUCTION

A decreasing interest in mathematics is not only a problem in technology and other STEM fields but also in fields like physiotherapy, nursing, tourism, and hospitality. Contextual framing of mathematics problems has often been suggested as means to motivate and engage students, but the related empirical evidence is still somewhat scarce (Beswick 2011). Appropriate contextual framing naturally depends on the topics and level of mathematics taught, but also on the age and interests of the learners. Kärkkäinen and Luojus (2019) discovered that more than 75% of Finnish high school students were indecisive of their occupational interests and had related concerns and worries. Hence, it can be deduced that the future working life is a meaningful context for many high school students and could provide a fruitful starting point also for contextualizing mathematics problems.

Mathematics-oriented teachers are usually more familiar with technology and STEM fields and, for that reason, may unintentionally neglect the application of mathematics in other fields. However, mathematics is needed everywhere. Expecting teachers to be able to provide a wide array of working life related mathematics examples is unrealistic and the teachers need to be supported in this by other professionals (Nieminen 2015). In our project, we create examples of mathematical problems related to all fields covered at our campus: technology, nursing and health care, business, tourism and hospitality and the arts. This helps teachers to motivate students, as they can illustrate where mathematics is needed in those areas.

Prior experiment of using engineering problems in high school mathematics teaching indicates that these exemplars can increase the student perception of practicality and usefulness of mathematics even if the examples are not taken from students' everyday life or situations that they can directly and personally relate to. In this case the practical value of mathematics was enhanced through meaningful connection of mathematics to the scientific problems and working life. (Nieminen 2015). Earlier studies show also that the perception of usefulness of mathematics for real life and future career increase the student motivation towards the subject (Summala 2020). Although the utility value of mathematics can be argued to increase specifically the extrinsic motivation of the students, it has been noted not to decrease the intrinsic motivation to learn (Porras, 2015).

Little and Jones (2010) point out possible dilemmas in the use of real-world contextual framing. First dilemma relates with the perceived utility of mathematics, where "[o]n the one hand, by making a connection between the abstract world of mathematics and everyday, or scientific contexts, we

Porras, P. and Naukkarinen, J.
Motivating Upper Secondary Students to Learn Mathematics with Working Life Exercises.
DOI: 10.5220/0010429102080215
In *Proceedings of the 13th International Conference on Computer Supported Education (CSEDU 2021) - Volume 2*, pages 208-215
ISBN: 978-989-758-502-9

are reinforcing the utility of mathematics as a language for explaining the patterns and symmetries of the 'real' world. On the other hand, if we manipulate and 'sanitise' real-world experiences to enable them to be modelled by a pre-ordained set of mathematical techniques, then the result can appear to be artificial and contrived." (Little & Jones, 2010, p. 137) Another dilemma concerns the effect of framing the questions in real-life contexts. On one hand this has been argued to help to solve the mathematical task by providing mental scaffolding, on the other hand it can complicate the task by making assumptions of certain context knowledge outside mathematics. (Ibid.) We aim to address both these dilemmas by searching and offering as genuine working-life problems as possible without extensive "sanitation", but with prerequisite context knowledge.

We believe that the high school students' motivation towards mathematics can be enhanced by presenting them mathematical tasks contextually framed in working-life problems from different occupations. In addition to enhancing the interest in mathematics, this is also hoped to provide students support in the development of their professional identities. The following sections provide an overview of the work we have conducted so far, and we finish with some ideas of how to investigate the outcomes and effectiveness of our solutions.

2 THE FRAMEWORK OF THE MOOC

One important aspect of planning the massive open online course (MOOC) was that it should not be confined to time or place. Upper secondary school mathematics is mainly studied over three years, so it is not reasonable to assume that students will use this MOOC in a short period of time. Repetition is also an important factor in deep learning (Roedinger & Pyc, 2012).

A second aspect was that the MOOC should appeal to both female and male students, regardless of whether they were planning futures in STEM fields or other areas. All students seeing the importance of mathematics would be a victory for us, especially if they initially considered mathematics as difficult and not needed after school.

Due to the first aspect, the use of the MOOC should be as automated as possible. The teacher(s) of this MOOC cannot be available whenever the students want to access it. In addition, if help is not available when needed, it may decrease motivation. Thus, a third aspect was to create the course in a form in which it provides hints and advises students during their learning without the presence of teachers. This kind of support is sometimes called instructional scaffolding (Reid et al., 2015).

2.1 Technical Setup of the MOOC

This section describes the technical elements of the course. Technical resources have a major effect on what and how the material can be produced. They may also influence a student's motivation and self-regulation levels. Unfortunately, online material does not always take advantage of many of the possibilities offered by the Internet (Kainulainen, 2006).

Moodle (www.moodle.org) is a free and open-based learning management platform that is commonly used in Finnish universities. As it enables automatic grading and has good analytic tools for analysing learning, it suited this course well. Moodle is easy to use, even if learners like the upper secondary school students have had no prior experience using it.

STACK is a computer-aided assessment package for mathematic questions on the Moodle platform (https://moodle.org/plugins/qtype_stack). It enables the randomizing of variables, as well as providing feedback based on a student's answer. Various question types can be formed, for example, algebraic, numerical, multiple choice (radio button or checkbox) and equivalence reasoning. When combining different kinds of question types, understanding can be reviewed in addition to calculation skills. STACK supports JSXGraph (http://jsxgraph.uni-bayreuth.de/wiki/) and GeoGebra for graphing. JSXGraph is more convenient if a graph is based on provided functions (either by a teacher or by a student as an answer), but GeoGebra enables curve-sketching problems and has 3D-graphing for better illustrations.

GeoGebra is an open-source dynamic mathematics software application (www.geogebra.org), in which geometry (2D and 3D), algebra, spreadsheets, graphing, statistics and calculus are presented in an illustrative way. For example, 3D geometric objects can be easily rotated with the software. It can have a major effect on understanding, especially if a student's spatial conceptualization is not strong. GeoGebra also allows teachers to write interactive lecture books with GeoGebra applets, create videos, etc.

Although the examples and exercises follow the curriculum of upper secondary level mathematics, in the real working life examples, there may be concepts that are not familiar to the students. As GeoGebra is commonly used in Finnish upper secondary schools, it was also selected by us as a main source for additional material for students. As mentioned earlier, GeoGebra can also be used in STACK questions.

Virtual reality (VR) makes it possible to study things in a simulated environment (Poitras, 2020). In some cases, studying in a simulated environment may even be safer than studying in the real world, such as with cliff blasting or handling dangerous chemicals by a beginner. Virtual reality is becoming more common, but it is still not an everyday activity for most of us. Because we are not able to take students to different kinds of workplaces during this project, we will make the most of virtual reality to give them simulated working life experiences as best as we can.

2.2 Learning Outline

This course was planned in close cooperation with local upper secondary school teachers. The teachers gave us insights and tips about difficult topics and pointed out the ones in which students do not see the connection to their future careers.

In upper secondary school in Finland, students can select either a long or short syllabus in mathematics. Even when selecting the long syllabus in mathematics, they can still skip physics and chemistry except for one compulsory course. Those students who select the short syllabus usually select only compulsory physics and chemistry. Hence, mathematical applications in even physics and chemistry remain out of reach for many students. For instance, vectors are mainly connected with forces, and forces are usually applied to technology in mathematics. Forces are rarely connected with bodily movements in examples, although they have a big role in areas like physiotherapy. In addition, vectors are studied only in the long syllabus, but students interested in physiotherapy studies mainly select the short syllabus and therefore make no connection between mathematics and their career interests.

Figure 1 presents one interactive graph in GeoGebra with a background photo selected. This example is in the teaching material to demonstrate how a kettlebell of 20 kg causes a force of 3.8 kN at point D if the lifting is done with the back, not the legs. Standing straight upright, this force on your spine would be equivalent to the force of supporting an object of 386 kg on the top of your head.

This is only one example in which a broader understanding of mathematics (and physics) would improve comprehension of a professional field, although there may not be a need to perform the actual calculations until later in one's education.

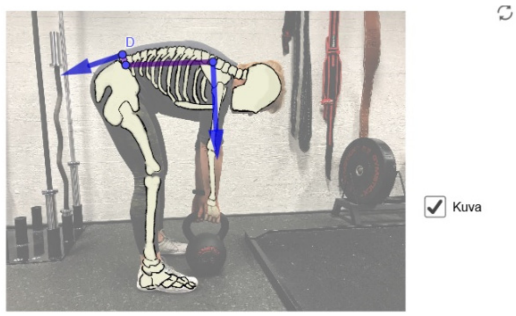

Figure 1: Vectors in physiotherapy.

2.2.1 Course Structure

The starting point in planning this MOOC was motivation. A person modifies his or her motivation from external settings and, little by little, intrinsic motivation may be aroused (Legault, 2016). Although most upper secondary level students may come to this MOOC for an external reward (to get a course mark for their curriculum), success in the exercises and real-life cases is hoped to also increase their intrinsic motivation.

The course is divided into separate exercises for the short and long syllabuses. The local teachers also discussed that the first-year mathematics could be on its own and the last two years presented together. The main reason for this was that the third year is more about preparing for the matriculation exam than studying new topics. Students can work on the course until they graduate from upper secondary school.

Although the course was divided into short and long syllabus content, the students were permitted to select any of the exercises. Some students in the short syllabus may have good calculation skills and may want to challenge themselves with exercises from the long syllabus. Also, those struggling in the long syllabus may want to try exercises from the short syllabus to improve their self-esteem.

One part of using extrinsic motivation to cultivate intrinsic motivation is to reward, not punish. Thus, students do not need to solve all the exercises of the package to get acceptable scores. The scores were weighted by their difficulty level to motivate students to select more challenging exercises. Applied problems were weighted twice as much as mechanical exercises, and exercises of the long syllabus were worth more points than corresponding exercises in the short syllabus.

This course was planned to be studied in close connection with upper secondary mathematics courses. Thus, extra lecture material was provided only in some special cases. There was an interactive GeoGebra book available in cases like that of the vectors mentioned earlier. Some topics were handled in videos (MP4 and H5P). These videos also provided guidance on correct answering techniques for the STACK questions. H5P is an interactive video format in which it is possible to add clarifying questions. In a question type called “Crossroads”, a student can be made to start a video again from a preselected time if he or she answers incorrectly.

Students do not need to do all the exercises from the selected package at once. The idea behind this is that it is better to do one than not to do anything. Secondly, the packages can contain question topics that have not yet been handled by their teacher, so they may not even have the knowledge to solve them. Thirdly, a student may notice the need to review earlier topics before continuing in exercises.

2.3 STACK Exercises

The Moodle activity called “Quiz” has different behavioural modes. The mode “Interactive with Multiple Tries” was used for all the exercises in this MOOC. In STACK questions, the feedback on a selected answer can be given both in a potential feedback tree and in an option with hints. In Figure 2, there is an example of solving a normal line equation. In the potential response tree, sub-question *a* is first checked, and it is indicated as incorrect. The second comment in the yellow box tells the student that the value of the slope is incorrect and that the equation was not checked. The third comment was given by the

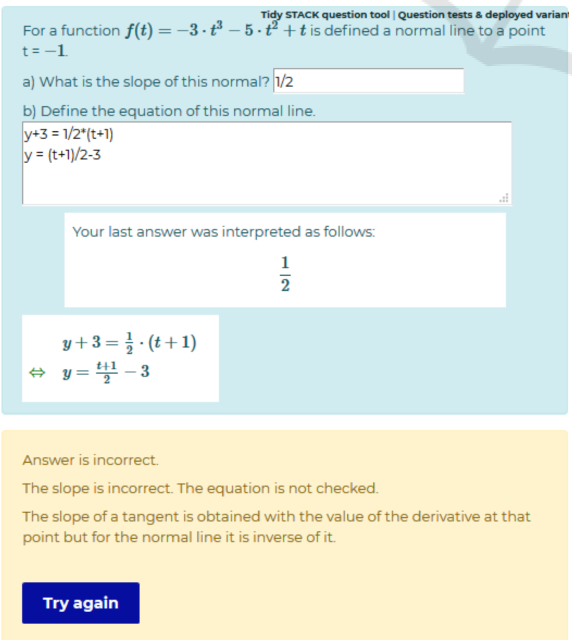

Figure 2: Feedback in STACK.

first hint. Hints make it possible for a student to attempt the same exercise several times to correct his or her mistakes. If the second attempted answer was incorrect, then the second hint would be given. Hints are general and cannot be customized based on a student’s answer. A small deduction on a student’s score is made whenever the answer is incorrect. With two used hints, the maximum score for the exercises would be 0.80 instead of one.

2.3.1 Equivalence Reasoning

In Figure 2, there is also an example of “Equivalence” reasoning in STACK. The last two white boxes are the validation boxes for the student’s answer: what the student entered and how STACK interpreted the given answer. In this case, all the given intermediate steps were logical, so no errors were found. This illustrates how entering answers or other mistakes are noted before any reference as to whether the answer is mathematically correct or not is made. As noted, the slope was incorrect, so this answer cannot be correct.

In Figure 3, the student has corrected the slope and uses it in the first row of question *b*. As a student has not yet corrected it in the second line, the red question mark can be seen at the beginning of the line. Thus, the student will need to change his or her answer before asking for it to be checked. This may help in motivation, as answers are not judged to be incorrect for keying or minor calculation mistakes. If a student solves the exercises on paper first (as instructed), a keyed solution is quite easy to review for further unnoticed mistakes.

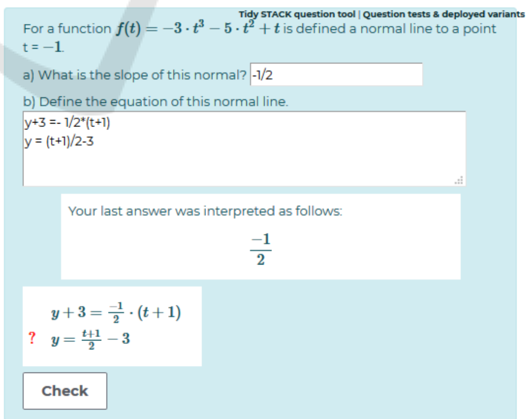

Figure 3: Error in an intermediate step.

2.3.2 Radio Buttons and Dropdown Menus

Mathematics is not only solving exercises with methods provided by a teacher but also understanding why they are used. Languaging (Joutsenlahti & Kulju,

2017) is an excellent way for a student to explain his or her thinking when solving an exercise. However, this kind of method is not suitable for a MOOC, in which the feedback is obtained instantaneously. One way for a student to express his or her thinking in a system with automatic feedback is with radio buttons and dropdown menus. Although the choices are pre-scripted, the process does force students to think through their solutions.

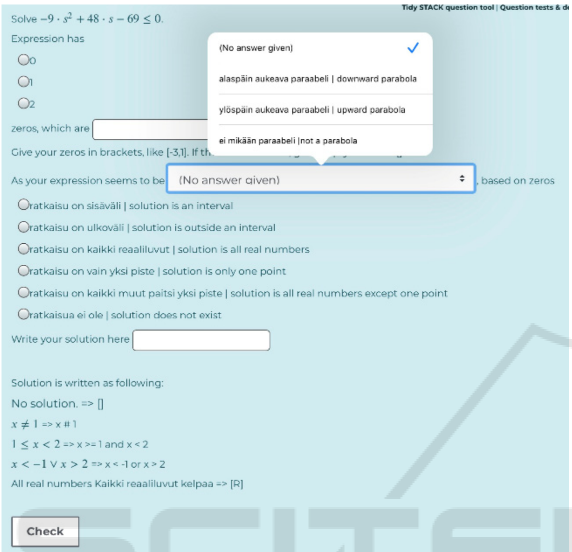

Figure 4: Example with radio buttons and a dropdown menu.

Figure 4 shows an exercise for solving a quadratic polynomial inequality. The main method of solving for zeros from the standard form has been omitted here. The main aspect is interpreting the solved zeros with the original inequality to form the solution.

2.3.3 Graphs for Feedback

One way of providing feedback for a student without showing the correct answer is with graphs. The equation of a line shown in Figure 5 is incorrect. Although the validation box on the right shows that the equivalence reasoning is correct, the student has given values of y in the wrong order. The line in the student's solution is shown together with the given points (rather than just having the system judge the solution to be incorrect). This hopefully helps students to figure out their mistakes and/or misunderstandings. This graph is not shown if there are errors in the equivalence reasoning for defining an equation (indicated by the red question mark at the beginning of a line).

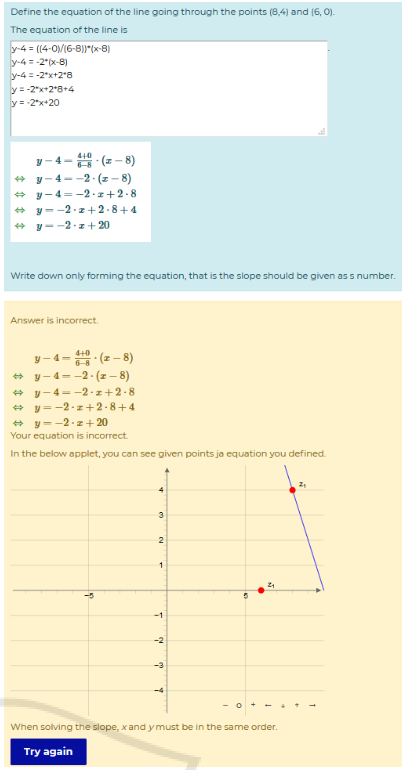

Figure 5: The equation of a line is defined incorrectly.

2.3.4 Applied Exercises

The applied exercises are verbal information, and only a final answer is required. There are different kinds of paths for solving applied exercises, and we did not want to restrict the solution to only one correct method. However, the final solution should be the same despite the method selected.

An exercise shown in Figure 6, is part of exercises in short syllabus. In this exercise, currency, amount, and the transaction fee are all randomized. Although the final answer is given, it will give hints for some most typical mistakes.

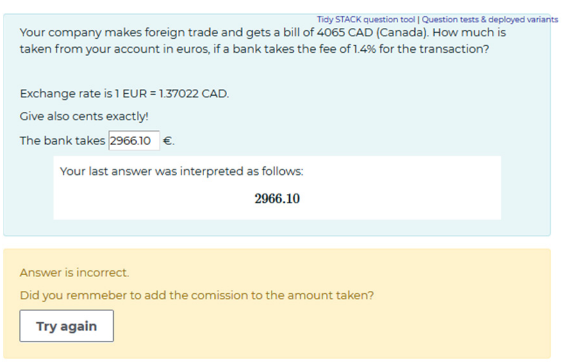

Figure 6: Applied problem in economics.

Students with their plans in social and health care as, for example, nurses or paramedics do not always see mathematics very important part of their work. In Figure 7, is one example of math needed in paramedics. If the amount oxygen is too low, it may be life-threatening. If there too much over the minimum requirement, there may not be enough space in an ambulance.

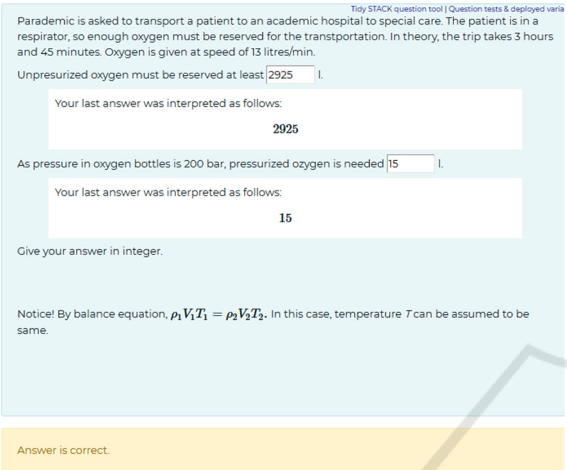

Figure 7: Paramedics also need mathematics.

In Figure 8, there is an example of exercise in geometry, which could be easily faced in civil or mechanical engineering. At the first sight, the exercise may look easy. The closer look reveals that actual radius is not given (but chord is) and must be solved. Solving this exercise requires knowledge in circles, cylinders, and density.

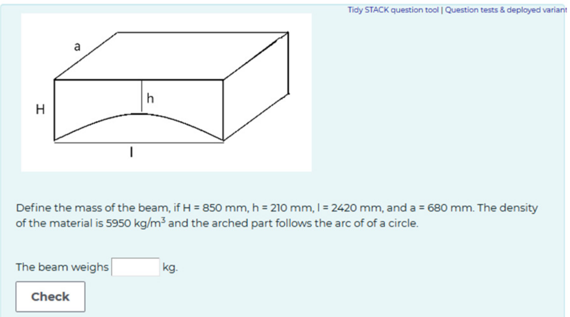

Figure 8: Geometry is important in technology.

2.4 Applying Mathematics in Virtual Reality

The upper secondary students who actively take part in this course will be asked to visit campus as a final activity (if COVID-19 restrictions allow it at the time). Part of this project was to produce a virtual reality experience in which students can solve applied problems related to working life. All the activities in the virtual reality will be connected to the exercises solved in the MOOC, but they will be extended versions of them.

We were able to liaise with *Pulsan Asema* (https://www.pulsanasema.fi/en/), which is a very popular resort in Lappeenranta, Finland. An inventory model of the resort was digitalized some years ago by Saimaa UAS, Finland, and our project can use that digital information in the VR model. The VR model is so accurate that even the location of the plumbing can be checked. This allows us to add actual working life exercises from civil engineering through hospitality in the same VR model. Figure 9 shows an exercise concerning hospitality. An order made by a customer is given on the screen to the right, a recipe is to the left of the window, and a cake tin needs to be found to see measurements. The volume of this "old" cake tin is not known, so the student must calculate it to know how much pastry is needed.

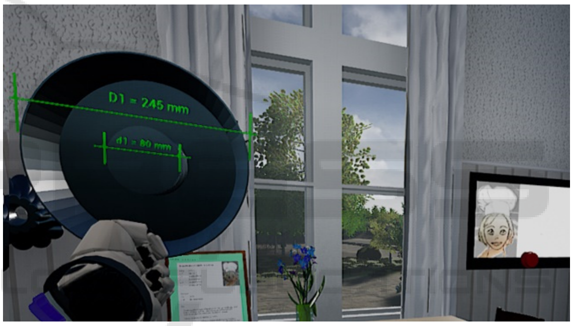

Figure 9: Exercise about an order made to Cafe.

3 NEXT STEPS

The project started in 2019. At that time, co-operation with upper secondary teachers in science, mostly in mathematics, occurred to find an appropriate level for the exercises. The teachers also provided ideas and identified topics that were neglected or were difficult for the students (and therefore required attention). For example, the concept of percentage is experienced as quite difficult by students in the short syllabus, although it is one of the most important topics in many postgraduate studies, like economics, tourism and hospitality.

The first students were enrolled in this course in June 2020. A total of 25 students were accepted to the course; 12 of them joined the Moodle platform, and one student from the short syllabus passed Part A (Part B will be available in spring 2021). This student was very active and asked for help several times. She did not lose her motivation, although there were several coding mistakes. Thanks to her, we were also able to code some different kinds of solution methods, which had not been anticipated by the teachers in engineering. As mentioned previously, there is usually not just one correct method to solve a problem in mathematics.

There are several possible reasons for a low commitment to the course. In general, the completion rate of MOOCs has been known to be weak (Alraimi et al., 2015); self-paced MOOCs especially appear to have low retention rates (Ihantola et al., 2020). In our MOOC, over half of the enrolled students did not even start the course. Of the 12 students that joined the MOOC platform, only a few, in fact, solved anything, and we suspect that most of them just joined the course to get access to material. However, the COVID-19 pandemic might have affected behaviour in the course in many ways. Because of the pandemic, the upper secondary school students thought that they could not get any summer jobs in 2020 and enrolled in this course to at least promote their studies. The situation was surprisingly better than assumed, and jobs became available, although later than normally. Another pandemic-related explanation is that because the students were studying online several months during spring 2020, they had become restless with online study and wanted a break from it. In any case, we need to study this situation more.

To better understand the situation and student experiences with the MOOC and to develop the exercises and materials further, we are currently collecting feedback with a form linked to the MOOC. The feedback is provided anonymously, and it can be targeted either to specific exercises or the course in general. In the future, we are hoping to be able to translate the course into English and Russian, as there are two special upper secondary schools in our area.

The correct feedback is important part of a good online exercise (Mäkelä et al, 2016), and especially if feedback is automated. If a student feels positive and encouraged after feedback, it may affect positively in motivation and in engaging their studies (Kennette & Chapman, 2021). Therefore, we collect students' observations of cases where the feedback should be improved to encourage instead of discouragement.

4 CONCLUSION

The worry of low interest in mathematics seems to be worldwide (Yeh & al., 2019, Azmidar & al., 2017). If the connection to one's own life cannot be captured, the interest is unlikely to arise. Like Legault (2016) mentions, the inner interest arise motivation and will to progress. The mathematics teacher of 2020 in Finland Piia Haapsaari, who was selected by mathematics teachers' union MAOL, mentions that she thought as a teenager not to be good enough in mathematics. A good teacher and appropriate teaching methods opened the lock: the success in given tasks increased the inner interest (https://esaimaa.fi/uutiset/kotimaa/33d7a047-b57a-4bec-af99-f4495a0bb901).

Based on the feedback we have received at the project steering group meetings and teacher webinars, local upper secondary teachers are excited about this course and material, want to learn more about it and want to offer it to students. Of course, the demand for upper secondary schools to cooperate with higher education from fall 2021 forward helps us as well. When this cooperation really starts, we will be able to better see how much students are able to utilise the course. One definite challenge is the already packed upper secondary school curriculum and the resulting heavy timetable of students, which may result in reluctance to engage in any non-compulsory activities.

As both, contextual framing and use of modern technology in the teaching of mathematics are complex issues with positive and negative aspects, the evaluation of the effect of MOOC on student motivation must be carefully planned and executed. We have started this work by establishing feedback channels to the students and teachers, but more and more versatile data is needed for proper data triangulation and analysis. This is an essential part of future work in the project.

ACKNOWLEDGEMENTS

We thank European Social Fund for funding this project (S21637).

REFERENCES

Alraimi, K., Zo, H., & Ciganek, A. (2015). Understanding the MOOCs continuance: The role of openness and reputation. *Computers & Education 80*, 28-38.

Azmidar, A., Darhim, D., & Dahlan, J. (2017). Enhancing Students' Interest through Mathematics Learning. *International Conference on Mathematics and Science Education* .

Beswick, K. (2011). Putting Context in Context: An Examination of the Evidence for the Benefits of 'Contextualised' Tasks. *International Journal of Science and Math Education 9*, 367-390.

Ihantola, P., Fronza, I., Mikkonen, T., Noponen, M., & Hellas, A. (2020, December 4). Deadlines and MOOCs: How Do Students Behave. *Frontiers in Education: Education for a Sustainable Future.* Uppsala, Sweden.

Joutsenlahti, J., & Kulju , P. (2017). Multimodal Languaging as a Pedagogical Model - A Case Study of the Concept of Division in Mathematics. *Education Sciences*.

Kainulainen, S. (2006). *Oppimista tukeva verkko-oppimateriaali – lähtökohtia verkko-oppimateriaalin tuottamiseen [Material Supporting Online Learning].* Retrieved from Theseus: https://www.theseus.fi/bitstream/handle/10024/19582/TMP.objres.30.pdf?sequence=1&isAllowed=y

Kennette, L., & Chapman, M. (2021). *Providing positive student feedback in an online environment*. Retrieved from Academia Letters: https://doi.org/10.20935/AL203

Kärkkäinen, J., & Luojus, L. (2019). *Ammatillinen identiteetti ja koulumotivaation toisen asteen opiskelijoilla [Professional identity and study motivation at upper secondary school].* Jyväskylän yliopisto.

Legault, L. (2016). Instrinsic and Extrinsic Motivation. In V. Zeigler-Hill, & T. K. Shackelford, *Encyclopedia of Personality and Individual Differences.* Springer International Publishing.

Little, C., & Jones, K. (2010). The effect of using real world contexts in post-16 mathematics questions. In M. Jourbert, & P. Andrews, *Proceedings of the British Congress for Mathematics Education.*

Mäkelä, A.-M., Ali-Löytty, S., Humaloja, J.-P., Joutsenlahti, J., Kauhanen, J., & Kaarakka, T. (2016). STACK assingments in university mathematics education. *44th SEFI Conference.* Tampere.

Nieminen, I. (2015). *Practical Mathematics in High School.* Tampere University.

Poitras, E. (2020). Foreword. In G. Akcayir, & C. Demmans Epp, *Designing, Deploying, and Evaluating Virtual and Augmented Reality in Education* (p. xiv). IGI Global Reference Book.

Porras, P. (2015). *Utilising student profiles in mathematics course arrangements.* Lappeenranta: Yliopistopaino.

Reid, D. R., Bowen, A. S., & Koretsky, M. D. (2015). Development of interactive virtual laboratories to help students learn difficult concepts in thermodynamics. *Chem. Eng.Educ 49 (4)*, 229-238.

Roedinger, H., & Pyc, M. (2012). Inexpensive techniques to improve education: Applying cognitive psychology echance eduational practise. *Journal of Applied Research in Memory and Cognition 1*, 242-248.

Summala, T. (2020). *Ensimmäisen ja toisen vuoden lukio-opiskelijoiden motivaatio matematiikassa [The first and the second year upper secondary school students' motivation in mathematics].* Itä-Suomen yliopisto.

Yeh, C., Cheng, H., Chen, Z.-H., Liao, C., & Chan, T.-W. (2019). Enhancing achievement and interest in mathematics learning through Math-Island. *Research and Practice in Technology Enhanced Learning (14)*.