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Upgrading Mathematical Skills for Professional Studies: The Role of Interactive Tasks and Self-Direction in Online Courses

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ABSTRACT

This paper presents an open online course aimed at those Not in Education, Employment, or Training (NEET). The course aims to give school dropouts, unemployed, and immigrants the opportunity to return or to enrol on studies. There are plenty of labour market training available for unemployed, but this does not necessarily contribute to further studies and thus improve one's own social position. Most entrance examinations often emphasise mathematical competence, which, especially for school dropouts and for the unemployed, may have remained at a low level or been forgotten over the years. This online course under development aims to address this shortcoming. As the target group is those currently outside the labour force, special attention must be paid to promoting learning/studying skills in the design of the online course. Students' self-direction skills are tested and based on their results, they are given tips on how to improve different aspects, as taking responsibility for one's own study is essential in an online course. In addition, the technical implementation of the course must be clear, and the instructions given on the tasks sufficient. The target group may not be as experienced as typical online course students, in which case even minor adversities may lead to dropping out. To maintain interest, the tasks are designed to be interactive, and they also provide feedback when doing the task, not only after the return.

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1 INTRODUCTION

According to the recent results of the OECD's PISA study, there is a visible decline in the level of competence in literacy, mathematics, and science in young people in Finland. Furthermore, the discrepancy in learning outcomes between pupils with an immigrant background and those without is one of the largest in the reference countries (Ministry of Education and Culture 2019). Based on Pietiläinen's report (2021), ninth graders' proficiency in mathematics has decreased compared to previous studies. Niemi et al. (2021) also reported that the level of competence in mathematics declines if a student does not enter upper secondary school. About 14% of young people do not have upper secondary education despite the unemployment rate being lower among the more educated (Witting 2021). Witting remarks that education has a generational component, as, on average, children from less educated families are less likely to enter tertiary-level education than others. In addition, students with less educated parents seem to have a higher dropout rate than students with highly educated parents. Addressing the underlying reasons is not the subject of this paper; instead, it frames the urgent need to help youth catch up with their studies.

The shortage of labour, especially in the technology sector, is growing, and the demands of digitalisation are not helping the situation. There are not enough technology students to fill the gap, as enthusiasm for studying technology is decreasing and only 60% of engineering students graduate according to Energiateollisuus (2021). Further, sufficient mathematics skills seem to predict the progress of engineering studies better than the actual educational background. Therefore, improving mathematics skills is important to support studying and improve graduation rates.

One principal factor in succeeding in professional studies is self-direction. Students who are excellent at regulating their studies usually progress well. Thus, it is important to understand the self-direction skills of students in order to provide them with the necessary tools and methods to succeed in their studies. Self-management and self-control are important skills that are also needed in working life.

The aim of this paper is to discuss psychological aspects needed to considerate in the course development for NEET and ways of implementing those aspects in course design. Those without recent education experience or a formal education may need more guidance to complete your studies independently, but also to work on online platforms in a technical point of view. Fostering their self-efficacy in mathematical subjects will aid their studies in mathematics (Niemi et al. 2021).

2 CHALLENGES IN ONLINE STEM EDUCATION

The popularity of online courses has continued to grow due to the continuous learning required in professional fields. Online courses offer flexibility in terms of time management, and they may be the only opportunity for those on the job to continue studying. Unfortunately, the reality is not as ubiquitous as one might imagine, and the dropout rates of courses are usually high. This section examines the reasons behind why students might drop out and how they could be considered in the course design.

2.1 Psychological aspects

Psychological aspects, like motivation and self-direction, are widely seen as key elements for academic success (Lao et al. 2017; Park, Moon, and Oh 2022). Henry et al. (2019) discuss how a student's own mindset (locus of control) or belief in their ability (self-efficacy, mindset) affects how they face challenges, their engagement in completing a task, and goal orientation. A fixed mindset refers to a person believing that intelligence and capacity are unchangeable, whereas a growth mindset refers to believing that these qualities are adaptable and can promote their skills over time and effort (ibid). Individuals with a fixed mindset place the blame on others when faced with failure, such as when the task is impossible, or a teacher does not explain things clearly. Whereas a person with a growth mindset sees difficult tasks as an opportunity to learn something new. In the case of failure, they just keep trying and find new ways to accomplish the task. Failure in this context refers to a gap between an expected or desired result and what is achieved (ibid).

Pintrich (2000) remarks that students have a mastery or performance orientation. Students with mastery orientation want to achieve competence and focus on the development of skills (ibid). Students with a performance orientation focus on external requirements, such as parental approval, grades, better salary, etc. These can also be further divided into approach (positive attitude) and avoidance (negative attitude). A mastery-approach orientation refers to a need to succeed in a task to meet an internally held standard, whereas a mastery-avoidance orientation tries to avoid failing an internally held standard (Henry et al. 2019). Performance approach orientation refers to non-negative and, often, positive associations with students' self-efficacy and academic performance (Bong 2009; Henry et al. 2019). Performance-avoidance orientation for avoiding failing to meet some normative standard may result in, for example, anxiety and the use of self-defeating strategies (Bong 2009). Individuals with a fixed mindset, performance goal orientation in general, or mastery avoidance goal orientation seem to have pessimistic thinking, make excuses, and seem to reduce effort already before failure. After failure, they think they are not good enough (ability), feel helpless, lose interest, or may even be burned out. As the target group of this paper is NEET, it is important to understand their orientation so that it can be addressed in course design and engagement.

2.2 Other reasons for dropping out

Several other attributes also influence the dropout rate: age, gender, academic experience, relevant technical and management skills, and personal variables (Shaikh and Asif 2022; Yılmaz and Karataş 2022). Bawa (2016) mentions that the learning level of college students seems to affect the probability of dropping out, as students with lower levels of learning are most likely to drop out. Students with prior experience of online learning seem to be more confident. It may be related to their technical proficiency, which is a factor of success when studying online (Bawa 2016; Shaikh and Asif 2022). That may be an issue with our self-study online course, as the target group may not have positive experiences with online learning. Shaikh and Asif (2022) also remarked that motivation aspects, like financial outcomes, may contribute to persistence in education.

A recent study from Brown (2023) describes the liminal experiences of students attempting to transition to tertiary education. In open university courses or online studies, students might encounter timetabling issues, alternative and new ways of studying and learning methods, and academic and institutional expectations. Brown also notifies that many students experience feelings of confusion, which may be perceived as a barrier to learning, as they adapt to a new learning environment where they are expected to demonstrate independence (Van Rooij et al. 2017; Pennington et al. 2017). Thus, the problems for those in transition are the same but much deeper in nature. Students may lack the prerequisite cognitive skills that are required in online learning environments.

2.3 Careful course design prevents dropping out

The previously mentioned aspects must be taken into account in the planning of the assessment and learning environment. The promotion of self-directed learning skills, the authenticity of the practice and well-timed feedback form the hallmarks of a good online learning model (Hurme, Porras, and Lähteenmäki 2023). Focusing on thinking and self-directed learning skills can therefore help our target group to complete the course.

Rasila et al. (2015) state that in order to build a pleasant user experience, the presentation of mathematics plays a key role. The mathematical content should be understandable regardless of the teacher's help, and the interaction between the student and the computer should be seamless. In addition, certain problems within materials and systems can later be identified indirectly by the students' training response data collected by the e-learning environment. User feedback and subsequent revisions to the e-learning platform and learning materials are necessary to improve the user experience.

Koedinger et al. (2015) showed that engaging in interactive activities within online courses yields more significant improvements in study outcomes compared to simply watching videos or reading theoretical material. Interactive activities foster active learning, which is more effective than passive knowledge acquisition, and the learning by doing method seems to be a reasonable premise for the design of an online course. However, combining the videos with interactive activities might help the students to get better grades. Rinneheimo (2017) found that students found videos useful for enhancing learning, with a majority wanting more videos in courses as they allow students to study at their own pace and revisit content as needed.

Paiva et al. (2015) emphasise that interactive learning modules such as interactive multimedia books, online quizzes, and educational videos create an effective online learning environment for studying mathematics in higher education. The study provided evidence that interactivity could effectively improve learning outcomes, as students with weaker basic math skills showed significant improvement. Velichová (2021) concludes that learning by doing enhances learners' motivation, enthusiasm, interest, attitude towards the whole learning process and desire to acquire new knowledge. An interactive approach improves opportunities to fill learning gaps in mathematics.

3 DESIGN OF THE ONLINE LEARNING ENVIRONMENT

On this course, all students have three modules to finish: learning skills, basics of mathematics, and professional-specific advanced tasks. Learning skills give basic knowledge on calculators, word processing, and spreadsheet computation. All skills required to successfully progress on mathematical subjects. Basic mathematics goes through lower secondary school mathematics and advanced tasks focus on professional field.

The theoretical framework (Hurme, Porras, and Lähteenmäki 2023) used for this online course is based on the idea of de Brujin and Leeman (2010). Four themes with descriptive features comprise the model: authenticity, activity design, guidance, and evaluation. Authenticity has a two folded meaning. It’s naturally considered with professional specific, advanced task. The idea is to use authenticity in to evoke an 'I can' identity (self-efficacy), for example, in people thinking about a possible career change. The pedagogical idea is to captivate the desire for learning by using suitable exercises from professional fields to promote further learning of the abstract terms and structures of mathematics and physics. These advanced tasks are divided into technology, business, social and health care, and tourism and nutrition. The student chooses one of these modules according to their professional interest.

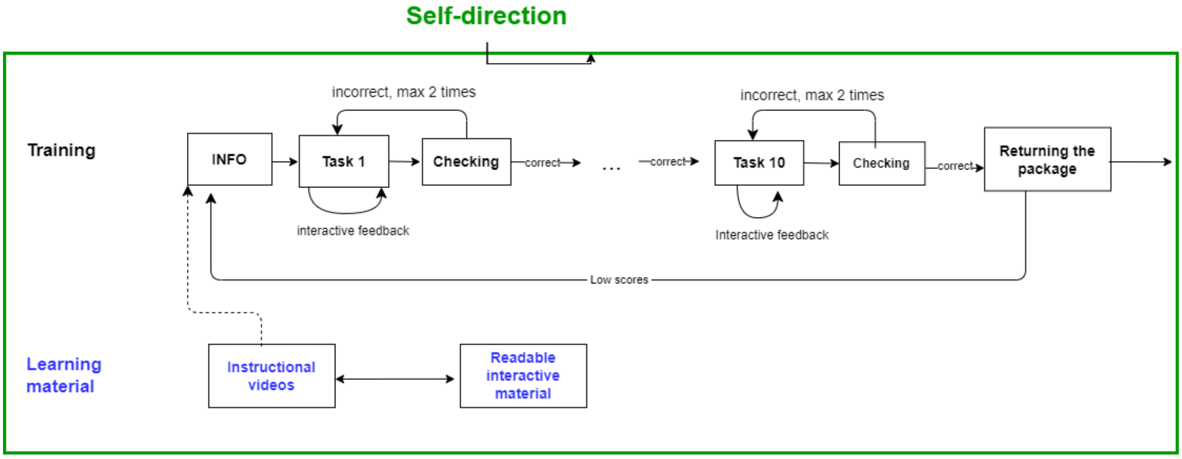

Fig. 1. Pedagogical model for online training

In the activity design, we follow the work of Bloom (1984) and Pelkola et al. (2018). The pedagogical model for online training of Hurme et al. (2023) to enwiden the basic conceptualisation and skills in mathematics is presented in Fig 1. This model emphasises the power of automated assessment and feedback to provide the seeds to support the growth in self-direction and learning for mastery of mathematical skills. Tasks are designed to provide feedback already during the execution, and not just after the checking. The purpose of this is to maintain student enthusiasm and reduce frustration. Winne (1982) states that if the learning environment is not inclusive, there is a risk of barriers for students who are less able to mediate or self-direct their own learning. If the interactive exercises and assessments performed are learner-centred, active student participation in a powerful learning environment will be promoted.

All students participate in competence level and self-regulation tests at the beginning of the course. These give them guidance which mathematical topics and self-direction aspects needs upgrading. The feedback in self-direction readiness test (Porras, Hurme, and Lähteenmäki 2023) will give the more detailed guidance the lower the scores received. After each module, students reflect their own learning with questionnaires. These include also self-direction aspects like planning and employment of time. The competence level test will be repeated after basics of mathematics to give feedback on learning.

3.1 Model for designing interactive exercises

Contemporary LMS (Learning Management Systems), such as Moodle, contain a range of interactive tasks, encompassing simple multiple-choice questions to sophisticated graphical queries, with automatic feedback being the unifying feature. STACK (System for Teaching and Assessment using Computer Algebra Kernel) is a prominent open-source e-assessment system operating within Moodle that integrates effectively with other platforms. The utilisation of tasks crafted by computer-aided algebraic systems requires extensive usage of STACK and Maxima (A Computer Algebra System). STACK utilises Maxima on calculations, but it also encompasses specific functions that are absent in Maxima but crucial for the generation of STACK tasks. For more detailed information on STACK, see Lähteenmäki et al. (2024).

A standard representation of interactive tasks requires students to type or select correct answers and passively receive immediate feedback. In this paper, interactive tasks are extended beyond that: students engage with interactive STACK tasks designed with JSXGraph, enabling them to interact with graphical interfaces using mouse or touch gestures. In the interactive task, hidden answer fields may contain diverse data types, such as coordinates of interactively manipulated objects, lists, or Boolean values.

Interactive tasks are increasingly prevalent in higher education, but effective design frameworks remain scarce. It is possible to generate interactive tasks with impact with open-source tools, but only if they utilise a learner-centred approach, simplify phenomena, and consider accessibility requirements to ensure compatibility with users' diverse needs. Interactivity should aid in comprehending underlying conceptual principles. Technical design should avoid complex structures, using clear instructions so the student can understand the task’s objectives.

3.2 Learner-centred task design and facilitative feedback

In an online course, when there is no student–teacher interaction, feedback plays a more significant role than in any other learning environment. The absence of a teacher and the live feedback without facial expressions and gestures truly challenge the learning process.

Feedback, whether it is related to guidance or assessment of activities, should be seen as an act affecting student’s future performance. Further, feedback should include answers as to why something is incorrect, how the error may be considered, and what may help solve the problem (Shute 2008; Torrance 2012; Brown 2023). These can enlighten the student on which areas are now under control, which positively affects learning. Brown (2023) and Hattie and Timperley (2007) also provide a way to provide feedback whilst maintaining a positive attitude in future learning by explaining how to reduce the identified gaps. By providing relevant positive feedback, we have the potential to affect the learner’s future performance and maintain the student’s desire for further studies.

The design of interactive tasks to ensure user-friendliness, intuitiveness, and inclusivity with a focus on pedagogically sound design play a central role. In designing interactive tasks for students, it is essential to adhere to a certain consistency: interactive elements should have consistent appearance and functionality to ensure they serve their purpose efficiently and intuitively. Particular attention must be paid to avoid confusing the student due to the perplexing functioning of the interactive task. In general, skilfully planned and executed programming should guide students so that incorrect answers do not result from syntax errors or improper response methods. It is crucial to strike a balance between simplicity and clarity of task presentation and avoid superfluous elements that may distract students.

The most common type of feedback is the immediate feedback received after the student checks the answer. If needed, the immediate feedback can be extensive, depending on the scope of the potential response tree. It has been demonstrated (Hurme, Porras, and Lähteenmäki 2023; Lähteenmäki, Hurme, and Porras 2024), that the graphical interface extends the ways of giving feedback. The graphical interface permits facilitative feedback to be shown dynamically based on the actual mouse interactions with the elements of the graphical interface. In Fig. 2 (left), there is an example of giving feedback for student during solving traditional equation task. A red question mark describes the stage at which an error occurs. Although we are not able to the specify the mistake, the instructions given below will give hints. This gives a student a possibility to fix the answer before checking.

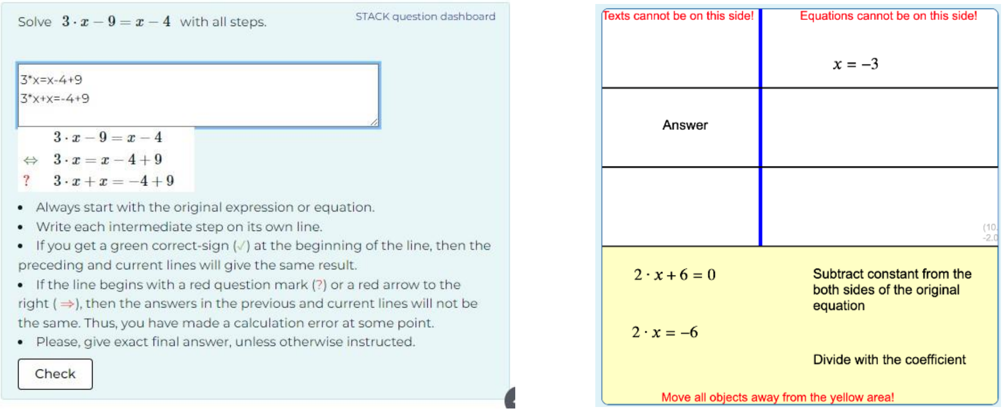

Fig. 2. Interactive feedback (left) and guidance (right) on solving equations

Gerhäuser et al. (2011) stress the benefit of using dynamical geometry software to introduce an innovative dimension to interactive tasks. Bach and Altieri (2021) confirm that dynamic geometry facilitates the development of challenging visual conceptual tasks while utilising JavaScript's versatility. In Fig 2 (right), the task utilises dynamic geometry. All steps are given but a student should order them correctly. This kind of drag-and-drop task enables forcing the student to understand intermediate steps (languaging) instead of simply following systematic instructions. The student is guided to drag objects to the correct side, but no feedback of correctness of the order is given during the task. Both kinds of tasks are needed to deepen the learning.

For example, in Figure 3, two different elements of facilitative feedback are used according to the inclusive design approach: dynamic attention messages and dynamic guidance messages. Only one row is intended to be selected in red. Thus, when a student selects another row, it turns red while the previous row reverts to black. If no row has been selected, a red dynamic attention message appears at the bottom of the window, reminding the student of the core task to be completed before checking the answer. Green arrow tips are the triggers of dynamic guidance messages that appear when hovering the mouse over them. Dynamic guiding messages can contain reflective questions or hints, just to mention a few. The main idea of dynamic guiding messages is that they point to one or many essential graphical elements and illuminate their meaning to students in a pedagogically sound way. All question types and their graphical elements must be explained thoroughly at the information part to decrease frustration.

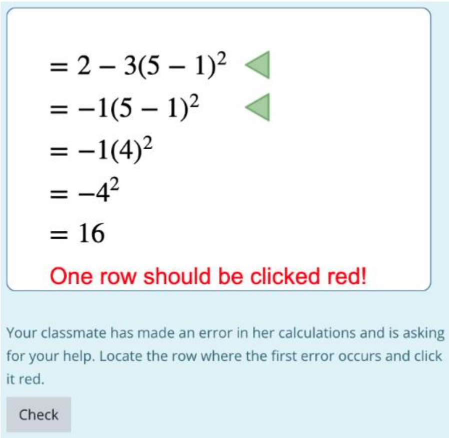

Fig. 3. Order of calculations

4 SUMMARY

The benefits arising from interactive tasks permeate all levels of education. In this paper, we demonstrate the effectiveness of these tasks in enhancing fundamental mathematical skills and solidifying foundational mathematical concepts in a purely online course. Although these aspects may not be the primary focus within higher education institutions, assuming students possess adequate competences in mathematical natural sciences, the decline in mathematical abilities is steep. Thus, there is an urgency to develop supportive measures to strengthen basic mathematical skills to facilitate successful higher education pursuits.

Poorly designed activities exacerbate the difficulties of learning online, so focusing on the level of assessment is a requirement. To promote students' learning in mathematics, both conceptions of mathematics and self-directed skills should be levelled up. Inclusive learning environments with interactive activities and learning by doing methods can address these issues.

This paper presented course aimed at NEET. We also introduced some interactive task types designed for the course to promote learning. The first pilot of this course will be during autumn 2024. At that time, we will see whether feedback and guidance has been helpful. The improvement in self-direction is not so easily explored, but indications of this are given by the ratio of students who passed the course to the number of participants. We are particularly interested in the feedback emerging on interactive exercise tasks: whether they are perceived as promoting learning, complicated, or more like gaming. This feedback affects course development.

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