Author(s): Hurme, Jarkko; Porras, Päivi; Lähteenmäki, Henry

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Enhancing Mathematical Skills for Vocational School Students Pursuing Undergraduate Studies

Jarkko Hurme, Oulu University of Applied Sciences, Finland
Päivi Porras, LAB University of Applied Sciences, Finland
Henry Lähteenmäki, South-Eastern Finland University of Applied Sciences, Finland

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Abstract
Over the past two decades, competence-based education has become a dominant trend in vocational and undergraduate education. The term competence-based education covers various conceptual ideas and practices arising from technical thinking in which education is seen as training competency, emphasising the development of complete vocational competence promoting autonomous identity and its continuous improvement. It should reflect how mathematics is taught at all levels of vocational education. As the PISA research has revealed gaps in skills in STEM subjects, our goal is to develop a powerful online learning model to promote access to undergraduate studies and employment for the disadvantaged in Finland. Their mathematical and scientific skills are analysed and trained online according to their self-direction. This facilitates graduating on time and applying for further studies. de Brujin and Leeman's original model of a powerful learning environment is enhanced, focusing now on online adaptive guidance, and supporting self-regulating skills. The initial state for improving mathematical competence and self-regulating skills is the formation of a vocational identity obtained in previous education. The model is delineated by the idea of cognitive apprenticeship, acquiring knowledge and skills to pursue further studies. Online reflection and constructive learning from authentic situations towards a more abstract construction of knowledge is viewed from sociocultural theory and its perspective on cognition. Understanding the mathematical self-concept of online learners can inform strategies for improving online mathematics education.

Keywords: STEM, Online Learning, Self-Directed Learning

Introduction

Education and needs do not always coincide in the Finnish labour market (Huttunen, 2022). There is a huge need for employees in the social, welfare, and healthcare sectors, while there is an oversupply of secretaries and travel agency officials, for example. The Technology Industries of Finland has reported that the technology industry will need 130,000 new experts within the next ten years, both with university degrees and vocational degrees (Teknologiateollisuus, 2023).

On average, 14 per cent of youth do not have a secondary education, even though unemployment is lower among the more educated (Witting, 2021). Witting remarks that education has a generational component: children of less educated families tend to educate themselves less at the tertiary level than other children, on average. Furthermore, students with less educated parents seem to drop out of studies more often than students with highly educated parents. The underlying reasons are not the subject of this paper but describe an urgent need to help youth catch up with their studies.

It is essential to overcome the mismatch in labour needs and provide the opportunity to access education at any time. Within the Finnish context, the threshold for applying for studies may be high, but suspicion of one's own mathematical skills may even prevent one from applying. For example, those applying to universities of applied sciences must take an entrance exam that includes a mathematical-logical part. Further, immigrants, who might fill these future roles, may be highly educated, but entering the Finnish labour market is often difficult without a Finnish degree.

This paper focuses on promoting access to education and employment for the disadvantaged (less educated, immigrants, and others) by improving their mathematical and scientific skills, thereby improving their chances of graduating on time, and applying for further education. Those without recent education experience or without a formal education might need a refresher on the basics, but those considering a new career entirely may want to improve their skills before taking the entrance examinations.

This paper discusses the role of competence-based education in pursuing vocational and professional education. Effective competence-based vocational education promotes self-directed and authentic learning within and beyond the workplace (de Brujin & Leeman, 2010). Those skills must be trained so those seeking new employment opportunities can pursue undergraduate education. In this paper, we aim to present a powerful online learning environment to fill in the gaps in STEM competencies. We explore the key features of the virtual learning environment. Dilemmas and encountered practical problematics of implementing online competence-based courses should be resolved when teaching, guidance and learning occur in practice.

Competence-Based Learning

Competence-based learning is deeply associated with learning and acquiring knowledge independent of time and place and is truly challenged in virtual learning environments. To ensure that students successfully pursue undergraduate studies, it is essential to underline that online courses must recognise and utilise the knowledge and related competencies of previous vocational studies and skills. In this paper, we develop a model considering that effective competence-based vocational education promotes self-directed and authentic learning.

Our model's concept of cognitive apprenticeships acknowledges learning to perform in practice and going towards a more general representation and understanding of STEM concepts than the initial vocational presentations. These specific professional skills and concepts lead students towards acquiring a more profound understanding, meta-cognitive skills and flexibility in STEM subjects.

We rely on a socio-constructivist view of students' awareness of their learning responsibility and the need to direct one's development to become a professional. To succeed in this, as the social interaction normal to in-situ classroom teaching is absent, developing interaction and feedback and fostering self-regulation skills makes it possible to retrieve demanded skills in STEM subjects of undergraduate studies.

Situated cognition refers to the idea that learning is situated in a social and functional context: it is about acquiring knowledge and skills and understanding how the knowledge is used in real-world situations (de Brujin & Leeman, 2010). It must be viewed so that knowledge is not just stored in the students' memory but is also distributed across tools and resources used to support learning. Learning from a situated perspective on cognition emphasises the importance of understanding the social and cultural context in which learning takes place and the role that this context plays in shaping the way that knowledge is acquired and used. Jossberger et al. (2010) state, concerning workplace simulations, that environments should be adaptive to learner's needs. It is also noticeable in online learning.

Characteristics of a Powerful Vocational Online Learning Environment

Even though COVID-19 increased the speed of the use of digital technology in teaching, it evoked new approaches to the design of teaching and learning. Digital technologies generate new ways of thinking about mathematics, the settings in which it is learnt and how mathematics teacher educators frame the new initiatives of initial and professional training (Engelbrecht et al., 2020). For the disadvantaged, the situation has not become any easier. Digital technologies have widely enlarged the number of new ways of visualising and learning mathematics and the settings in which it is learnt. Even if this sounds appealing to educators, the same may not be true for students. The findings of Llinares and Valls (2010) suggest that incorporating the analysis of video clips from mathematics lessons and engaging in online discussions can be an effective way to support the learning process of prospective teachers. Keep in mind that transferring this idea to other types of learners not so involved in education and the absence of online discussions must be recompensed via self-directed skills, motivation, reflection, and the system's structural guidance.

We frame the initiative skills of vocational STEM competence to build an operating model for online learning to promote access to undergraduate studies. By designing a powerful online model focused on self-directed learning and the construction of knowledge, we invoke students' professional development. We will describe the resources for how this will be implemented. Our developed model is based on the scheme proposed by de Bruijn and Leeman (2010). The powerful learning environment originally comprised a mix of instruction with features like active and reflective training and a delineated focus on authentic and self-directed learning. The original models are further developed, focusing on guidance, self-regulated learning and promoting the student's active role in learning and reflection. Four themes with descriptive features comprise the model:

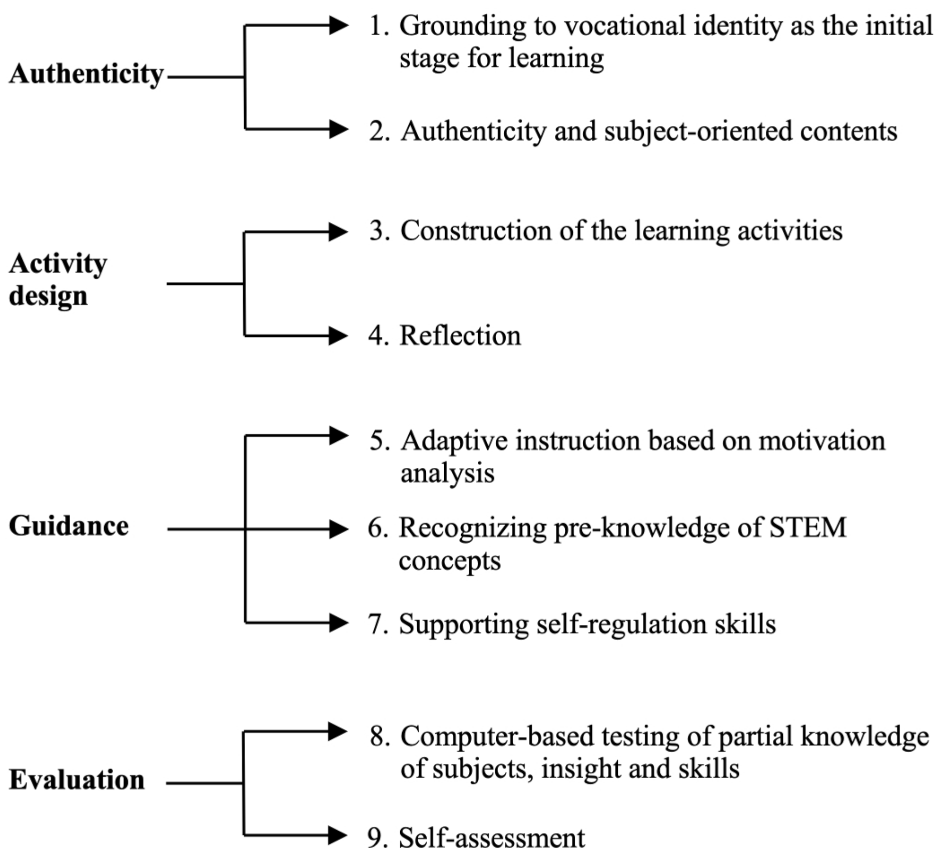

Figure 1: Characteristics of the pedagogical model for online studies promoting SDL skills.

The model presented in Figure 1 is based on the idea of de Bruijn and Leeman (2010) and is revised in the view of online learning. Authenticity is not seen here as a professional identity but rather as a way 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.

Guidance plays a remarkable role in online courses. Activity design is based on Bloom's Learning for Mastery (Bloom, 1968, 1984; Pelkola et al., 2018). Different exercises with similar complexity and degree of difficulty vary in each activity package. The computer algebra system STACK enables feedback to be interactive and makes it possible to learn from mistakes. Each package of exercises allows multiple trials, enabling monitoring of their own progress. Examples are presented later in this paper.

Computer-based evaluation is essential in online courses. Each course section (mathematics, physics, and general studying skills) can be studied independently. The student's learning for mastery is tested after completion of the mathematics and physics parts. Self-assessment and reflection provide results on how successfully SDL skills developed, and the final mathematics exam indicates the improvement in skills in these subjects.

The chosen themes reflect authentic and constructive learning from a situated perspective on cognition from various fields of vocational education. The tools and resources used to support learning are crucial in students' individual learning processes. This means that learning is not just about acquiring knowledge but also developing the ability to use that knowledge in real-world situations.

Self-Directed Learning

Radmehr and Goodchild (2022) discovered that the COVID-19 pandemic revealed that it is not easy for mathematics lecturers to be aware of many challenges students may encounter through online education. This must be considered when the aim is to develop a standalone online course for the disadvantaged. Their second finding was that advanced technology and the internet were not entirely successful in supporting many students to learn mathematics.

The pedagogical model used for learning activities in Moodle (Porras et al., 2023) utilises a modified Bloom's model for a successful learning process. It is based on reflective learning and is now implemented in a vocational framework. The learning model emphasises the power of automated assessment and feedback to provide the seeds to support growth in self-direction and learning for mastery in the discourse of STEM competencies.

A study by Artino (2008) reveals that developmental differences exist in students' self-regulatory beliefs and behaviour-adaptive academic outcomes in online settings. According to Alotaibi and Alanazi (2021), students with highly cohesive conceptions of mathematics tend to have higher self-directed learning skills than students with fragmented conceptions of mathematics. Fragmented understanding predicts low mathematics achievement. Students with fragmented conceptions develop lower-level learning skills, e.g., memorisation. The approach represented here tries to influence learning outcomes via conceptual gains promoting self-direction skills.

Self-direction learning (SDL) and self-regulation learning (SRL) are the focus of learning processes. They are widely used and often interpreted as the same. As Saks and Leijen (2013) noticed, these two initially crucial concepts have much in common and are divided into two distinct approaches or discourses. The main difference is that SDL handles adult education and is practised mainly outside the school environment, whereas SRL is practised in the school environment. As SRL focuses on the school environment, teachers usually set the tasks, and there is not much room for a person to plan a place or a time to do the task. In self-paced learning, students can choose the timing but neither the material nor the resources (Robinson & Persky, 2020). Self-paced learning requires motivation, but it happens in the school environment. Online learning is mainly done outside the school environment and, therefore, requires planning, for example, timing and place. Furthermore, the structure of the target group is socially diverse and demands aspects of lifelong learning. The vocational background needs to be considered as a high motivational factor. Therefore, the SDL approach is more valid for this study.

Self-Directed Learning Readiness Scale

Online learning is fragmented: learners use fragmented time and thinking methods to acquire knowledge (Liang et al., 2018). Thus, an independent online course requires determination from the participant to complete the course: it is widely reported that dropout rates of MOOCs are high, especially at the beginning, e.g. Ihantola et al. (2020) and Onah et al.

(2021). These studies are done among university students, who presumptively possess good studying methods. Our target group is the disadvantaged, whose previous studies may have been a long time ago. If their studies have been incomplete or they have not even applied to post-comprehensive school education, then the students may lack the most critical element for the progress of their studies, i.e., self-direction. Self-directed learning involves, among other things, goal setting, time management, environment structuring and help-seeking. In other words, a learner takes control of their learning. As Park et al. (2022) mention, online/distance learning based on self-directed learning strategies enhanced students' achievement, their beliefs, and their perception of long-term future possibilities, suggesting that readiness for self-directed learning is essential for progressive learning.

One part of this project is to study how students in online courses can be supported to maintain focus till the end. If the student's readiness for self-directed learning is known, they could be individually guided to promote their weaker aspects of self-direction. Grow (1991) introduced four types of self-directed learners, their pros and cons and what kind of teaching suits them best. This division was done when online lecturing was not so common. It is interesting to see how well this advice works in independently studied online courses and how easily it can be applied from a teacher's point of view.

There are several tests for testing readiness for self-directed learning (M. Fisher et al., 2001; Guglielmino, 1978; Williamson, 2007). Fisher et al. (2001) developed their original self-directed readiness scale test with 40 statements. Fisher and King (2010) revised test having 29 statements. We selected the revised test by Fisher and King (later referred to as SDLRS). One of the excluded statements was 'I am logical'. The test was designed for and tested with nurses, and this may not be the most relevant statement for them. However, this project is about studying mathematics and sciences, where logical thinking and acting are relevant. For that reason, this statement is included in our test. As they mention (M. Fisher et al., 2001), measuring SDL readiness needs to be done within a specific context.

SDLRS studies three aspects of self-directed learning: self-management, desire for learning and self-control. In an ideal situation, all statements would be mixed, and some would be negatively phrased. Our online course will be on the Moodle platform. To give individual guidance, we need to know which aspects (or maybe all) of self-directed learning a student needs direction. Unfortunately, Moodle does not contain a Likert scale activity where the mixed individual questions could be individually added to a specific variable value. A Likert scale can be found in the Questionnaire activity, but it only adds up the points given. Thus, negative statements cannot be used either. For these reasons, we separated all aspects into their own queries.

Students' motivation and self-regulation skills are investigated using a self-directed learning readiness scale (SDLRS) when entering the course. Students get feedback after answering a query. Feedback is categorised into three levels by 75% and 45% from maximum scores. The lower the scores are, the more detailed instructions are given to a student.

Competence Level Test in Mathematics

The online course covers mathematics and physics and a section on general studying methods and basic skills like the usage of calculators and formula books. Each section is worth one ECTS and can be done separately. For example, a person interested in tourism and hospitality does not need physics as much as automation or maintenance. However, someone interested in technology must have some knowledge of physics. Mathematics being common to all participants, the topics must be selected carefully.

In spring 2023, students at regional vocational schools in three provinces around Finland participated in a competence level test in mathematics. Although most students were from technology, there were participants also from the service industry. The test was done under supervision in a classroom without a calculator or a formula book. The topics covered middle school mathematics. We used the information obtained from the test to determine the topics covered in the online course. The common part in universities of applied sciences entrance exams is based on middle school mathematics. Calculators and formula books are also not allowed: mental calculation skills must be strong, although questions are multiple-choice.

Participants of this online course will do the same but with a randomised test at the beginning of the online course. After completing it, they will repeat the test to see their progress. These tests will be time-limited to 30 minutes, and time will be running down visibly. There is a similar situation for entrance exams, so they can practice solving exercises under pressure. When the final test results are analysed with SDLRS, we will see whether learning models helped achieve the desired knowledge.

STACK-Based Testing of STEM Competence

STACK is Moodle's leading open-source computer-aided assessment system plugin (https://stack-assessment.org/). It enables the creation of randomised mathematical questions in which the answer can be typed in multiple ways, for example, an algebraic expression, an integer, or a float together with SI units, to mention a few of the most common ones. Moodle also supports coding multilingual STACK tasks through the Multilang filter so that the students see the tasks in the respective language they selected from the Moodle language settings. Porras and Naukkarinen (2021) introduced STACK's basic functionalities and more advanced interactive usage cases when combined with the JavaScript library JSXGraph.

Moodle is a widely used virtual learning environment. It provides comprehensive tools for increasing students' activity and independence in learning (Takaendengan & Santosa, 2018). Porras et al. (2023) presented a desired model for STACK-based exercises, ensuring students achieve a deep and comprehensive understanding of a subject and reduction of learning gaps before moving on to more advanced topics. In this model, learning is based on Bloom's Learning for Mastery (LFM) (1968, 1984). Mastery is achieved here using automated assessment and feedback to provide the seeds to support growth in self-regulation and learning for mastery in mathematical skills.

Following Bloom's LFM, one essential focus is to increase students' conceptual understanding that benefits the students so that mathematics is not merely seen from the surface learning point of view as memorising a mechanical step-by-step process but engaging in deep learning. Various kinds of interactive exercises testing conceptual understanding can be programmed by combining JSXGraph with STACK. One example is given below.

In the exercise of Figure 2, a student is asked to move the elements from the yellow window into their correct places: equations into the left-hand-side column's windows and written text to the right-hand-side column's windows. STACK is utilised to determine if the elements are in the correct window, and after clicking “check”, student receives automatic feedback in the form of a potential response tree (PRT). Beyond the common post-check PRT feedback, not so common pre-check annotations are also utilised. Students can see the pre-check annotations in real time while dragging the elements as the visibility of the annotations is triggered according to the coordinates of the elements. Real time annotations become handy in cases that demand immediate actions such as if the student moves the equations beyond the blue vertical line on its right side or the text elements to its left side. In these cases, the annotations will state that the equations ought to be on the left side and the text elements on the right side. If some elements are not dragged away from the yellow area, an annotation will state that no elements shall be left within the yellow area. Thus, real time annotations may help the students to notice their inadvertent mistakes and do initial corrective actions to evade losing points in vain when checking their answers.

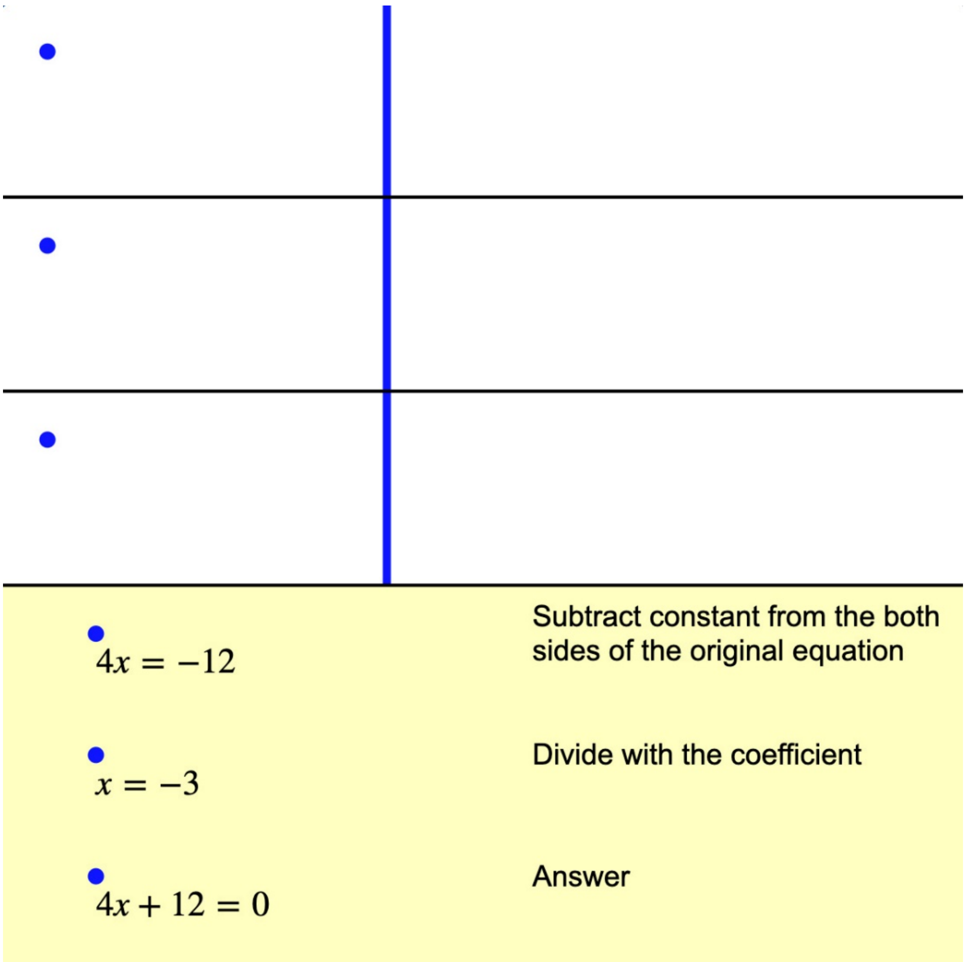

Figure 2. Interactive exercise testing the student's conceptual understanding of the steps for solving a linear equation. STACK is used to randomise the numbers for the equations.

In Figure 2, the equation-solving steps are written out on purpose. It has been proven to enhance learning if the student writes out the mathematical processes or deals with written processes, not solely using mathematical notations (Porras, 2015). The texts will be shown in English or Finnish, depending on the language the student is using in Moodle. Following Bloom's LFM, after the student understands the connection between written-out processes and equation-solving steps, the next step would be introducing the mathematical notations of making the same mathematical operation on both sides of the equation.

The initial state of Figure 2 is the most challenging case because the student needs to move all the elements. However, the exercise can be modified so that, for instance, one or many of the equations are initially in the correct windows, and then the student is asked to move merely the written text to the correct windows. Consequently, different difficulty levels can be created by slightly modifying the same exercise.

The PRT is shown in Figure 3. It is designed for checking the validity of students' answers, carrying out automatic scoring and generating automatic feedback for the student. The PRT is designed to state if the student's answer is correct or incorrect, but it can also guide the student's understanding and concept formation with thought-rising hints and thought-provoking questions.

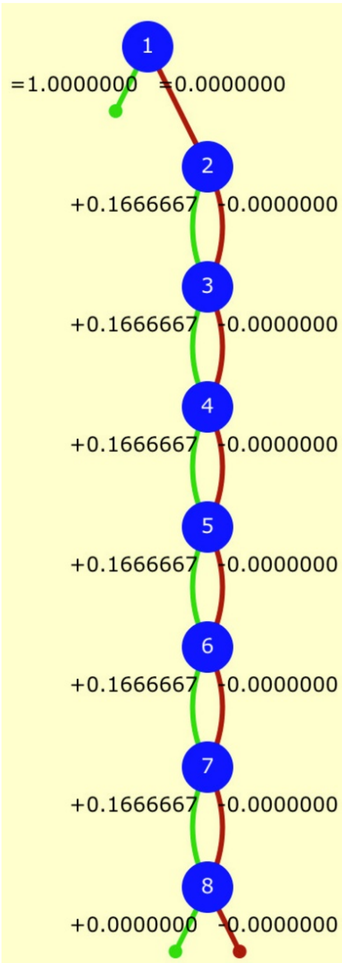

Figure 3. The PRT is utilised in scoring and automatic feedback.

The PRT is organised into a tree with eight nodes. Each node represents a test that is done to determine if some parts of students' answers are correct or incorrect. If the test is passed, a movement is made along the green lines. If the test fails, a movement is made along the red lines. The small green and red dots represent the states where no more tests are executed, and the algorithm stops. The numbers indicate the scoring of points as a percentage of the maximum points.

The PRT is structured as follows: beginning at the root (node 1), STACK checks if all elements are within the correct respective windows and gives feedback if everything is correct. It gives full points, and no more tests are executed as the algorithm stops at the first small green dot. If even one element is within the incorrect window, the node 2 to 8 tests are executed. The node 2 to 7 tests check if the individual six elements are within the correct window, and feedback is given stating whether the element is within the correct window. At node 8 STACK checks if the equation-text pairs are horizontally correct even if their location is incorrect. Feedback is given stating that one or more pairs are horizontally correct, but they need to be moved vertically into the correct row.

The above example shows the power of utilising STACK together with JSXGraph. Moreover, interactive exercises and exercises including a visual aid benefit people with dyslexia or who are not proficient in Finnish or English to grasp the underlying idea of the exercises better. Through the interactive exercises, students can play around and discover mathematics and physics by themselves, hopefully increasing their motivation and self-directed learning readiness.

Conclusion

In this paper, we have introduced our pedagogical model to increase the self-efficacy and self-direction of the disadvantaged to continue their studies. It is based on a model for developing vocational identity in the context of competence-based vocational education and Bloom's Learning for Mastery. Although the purpose of this online course is to provide sufficient tools in mathematics and physics for further studies, in addition to these, the student's self-esteem, i.e., self-efficacy and self-direction, must be improved. Scientific skills are not enough if the level of mental competence is insufficient.

Bloom observed that students learn much better with individual tutors (Bloom, 1984). It is difficult to arrange a personal tutor no matter what kind of study it is. However, online platforms such as Moodle provide more opportunities for this than traditional classroom teaching. In STACK, this has been taken into account with task-specific feedback. The student receives feedback on the intermediate assignment before submission (equivalence reasoning) and on all assignments after submission. Post-submission feedback can be very detailed, as the limit is mainly the author's interest in forming a PRT (Porras, 2021; Porras & Naukkarinen, 2022).

Crawford et al. (1998) introduced an interesting instrument for studying how students comprehend mathematics: fragmented or cohesive. Fragmented refers more to surface learning and cohesive to deep learning. Based on studies (Alotaibi & Alanazi, 2021; Crawford et al., 1998), fragmented conception is connected with lower readiness for self-directed learning. Alotaibi and Alanazi (2021) suggest that 'students' conceptions of mathematics may play a filtering role that regulates students' thinking and actions in mathematics learning and teaching; this is key for developing self-directed learning skills'. According to them, both conceptions of mathematics and self-directed skills should be levelled up to promote students' learning in mathematics. In the future, it would be interesting to study how fragmented learning is among disadvantaged people and how this fragmentation could be reduced.

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References

Alotaibi, K., & Alanazi, S. (2021). The influences of conceptions of mathematics and self-directed learning skills on university students' achievement in mathematics. *European Journal of Education*, *56*(1), 117–132. https://doi.org/10.1111/ejed.12428

Artino, A. (2008). Promoting Academic Motivation and Self-Regulation: Practical Guidelines for Online Instructors. *TechTrends*, *52*(3), 37–45.

Bloom, B. (1968). Learning for mastery. *Evaluation Comment*, *1*(2). https://files.eric.ed.gov/fulltext/ED053419.pdf

Bloom, B. (1984). The 2 Sigma Problem: The search for Methods of Group Instruction as Effective as One-to-One Tutoring. *Educational Researcher*, *13*(6), 4–16.

Crawford, K., Gordon, S., Nicholas, J., & Prosser, M. (1998). University mathematics students' conceptions of mathematics. *Studies in Higher Education*, *23*(1), 87. https://doi.org/10.1080/03075079812331380512

de Brujin, E., & Leeman, Y. (2010). Authentic and self-directed learning in vocational education: Challenges to vocational educators. *Teaching and Teacher Education*, *27*, 694–702.

Engelbrecht, J., Llinares, S., & Borba, M. (2020). Transformation of the mathematics classroom with the internet. *ZDM Mathematics Education*, *5*.

Fisher, M. J., & King, J. (2010). The self-directed learning readiness scale for nursing education revisited: A confirmatory factor analysis. *Nurse Education Today*, *30*(1), 44–48. https://doi.org/10.1016/j.nedt.2009.05.020

Fisher, M., King, J., & Tague, G. (2001). Development of a self-directed learning readiness scale for nursing education. *Nurse Education Today*, *21*(7), 516–525. https://doi.org/10.1054/nedt.2001.0589

Grow, G. (1991). Teaching learners to be self-directed. *Adult Education Quarterly*, *41*(3), 125–149.

Guglielmino, L. M. (1978). *Development of the Self-Directed Learning Readiness Scale*. University of Georgia.

Huttunen, O. (2022, April 5). *Näissä ammateissa on nyt pahin pula tekijöistä – katso lista*. Ilta-Sanomat. https://www.is.fi/taloussanomat/art-2000008729567.html

Ihantola, P., Fronza, I., Mikkonen, T., Noponen, M., & Hellas, A. (2020). Deadlines and MOOCs: How Do Students Behave in MOOCs with and without Deadlines. *2020 IEEE Frontiers in Education Conference (FIE)*, 1–9. https://doi.org/10.1109/FIE44824.2020.9274023

Jossberger, H., Brand-Gruwel, S., Boshuizen, H., & van de Wiel, M. (2010). The challenge of self-directed and self-regulated learning in vocational education: A theoretical analysis and synthesis of requirements. *Journal of Vocational Education and Training*.

Liang, K., Wang, C., Zhang, Y., & Zou, W. (2018). Knowledge Aggregation and Intelligent Guidance for Fragmented Learning. *Procedia Computer Science*, *131*, 656–664. https://doi.org/10.1016/j.procs.2018.04.309

Llinares, S., & Valls, J. (2010). Prospective primary mathematics teachers' learning from on-line discussions in a virtual video-based environment. *Journal Math Teacher Education*, *13*, 177–196. https://doi.org/10.1007/s10857-009-9133-0

Onah, D. F., Pang, E. L., Sinclair, J. E., & Uhomoibhi, J. (2021). An innovative MOOC platform: The implications of self-directed learning abilities to improve motivation in learning and to support self-regulation. *Campus-Wide Information Systems*, *38*(3), 283–298. https://doi.org/10.1108/IJILT-03-2020-0040

Park, K., Moon, S., & Oh, J. (2022). Predictors of academic achievement in distance learning for nursing students. *Nurse Education Today*, *108*, 105162. https://doi.org/10.1016/j.nedt.2021.105162

Pelkola, T., Rasila, A., & Sangwin, C. (2018). Investigating Bloom's Learning for Mastery in Mathematics with Online Assessment. *Informatics in Education*, *17*(2), 363–380. https://doi.org/10.15388/infedu.2018.19

Porras, P. (2015). *Utilising student profiles in Mathematics course arrangements*. Lappeenranta University of Technology.

Porras, P. (2021, June 9). *Some Stack issues faced during programming exercises for TyöMAA project*. Zenodo. https://doi.org/10.5281/zenodo.5036063

Porras, P., Hurme, J., & Lähteenmäki, H. (2023). *Improving mathematical skills towards undergraduate studies*. Mathematics Teaching in Engineering Education (MSIG2023).

Porras, P., & Naukkarinen, J. (2021). Motivating Upper Secondary Students to Learn Mathematics with Working Life Exercises: *Proceedings of the 13th International Conference on Computer Supported Education*, 208–215. https://doi.org/10.5220/0010429102080215

Porras, P., & Naukkarinen, J. (2022). Developing an Interest in Mathematics with Occupational Exemplars. In B. Csapó & J. Uhomoibhi (Eds.), *Computer Supported Education* (pp. 115–129). Springer International Publishing. https://doi.org/10.1007/978-3-031-14756-2_7

Radmehr, F., & Goodchild, S. (2022). Switching to Fully Online Teaching and Learning of Mathematics: The Case of Norwegian Mathematics Lecturers and University Students During the Covid-19 Pandemic. *International Journal of Research in Undergraduate Mathematics Education*, *8*, 581–611. https://doi.org/10.1007/s40753-021-00162-9

Robinson, J. D., & Persky, A. M. (2020). Developing Self-Directed Learners. *American Journal of Pharmaceutical Education*, *84*(3), 847512. https://doi.org/10.5688/ajpe847512

Saks, K., & Leijen, Ä. (2013). Distinguishing Self-directed and Self-regulated Learning and Measuring them in the E-learning Context. *Procedia - Social and Behavioral Sciences*, *112*, 190–198. https://doi.org/10.1016/j.sbspro.2014.01.1155

Takaendengan, B. R., & Santosa, R. H. (2018). Using moodle to improve self-directed learning of mathematics in vocational school. *Journal of Physics: Conference Series*, *1097*, 012121. https://doi.org/10.1088/1742-6596/1097/1/012121

Teknologiateollisuus. (2023, May 5). *Teknologiateollisuuden kasvu on jämähtänyt mutta osaajatarve pysynyt vahvana (Growth in the technology industry has stagnated, but the need for experts has remained strong.)*. Teknologiateollisuus. https://teknologiateollisuus.fi/fi/ajankohtaista/tiedote/teknologiateollisuuden-kasvu-jamahtanyt-mutta-osaajatarve-pysynyt-vahvana

Williamson, S. (2007). Development of a self-rating scale of self-directed learning. *Nurse Researcher*, *14*, 66–83. https://doi.org/10.7748/nr2007.01.14.2.66.c6022

Witting, M. (2021, May 28). *Lukio, amis vai pelkkä peruskoulu? – Perusopetuksen jälkeisillä valinnoilla on usein kauaskantoiset vaikutukset*. Tilastokeskus. https://www2.tilastokeskus.fi:443/tietotrendit/artikkelit/2021/lukio-amis-vai-pelkka-peruskoulu-perusopetuksen-jalkeisilla-valinnoilla-on-usein-kauaskantoiset-vaikutukset/

Contact email: jarkko.hurme@oamk.fi