An education model for customized and flexible networked learning courses for working engineers

Stefan Forsström

Department of Information Systems and Technology, Sensible Things that Communicate Research Centre, Mid Sweden University, stefan.forsstrom@miun.se

Abstract

The area of computer and electrical engineering is under constant evolution which leads to lifelong learning being an important aspect for being a long term successful working professional. This work presents an education model for creating customized and flexible courses at advanced level for these working professionals. We have approached this work from the educator's point of view and the focus will be on the teaching model and our results from implementing the model during the last two years. Including how we created these need and trend-based education offerings, the course execution inspired with micro-learning and flipped-classroom pedagogics, and our work with creating win-win possibilities within the courses for the working professionals and the companies they work for. Finally, we will present our experiences and lessons learnt, ending with a plan for our upcoming courses and our refined model in our ongoing future work.

Keywords

Engineers, Expert competence, Further education, IoT, ML, Lifelong learning, Working professionals

Introduction

There is a need for lifelong learning and continual professional development in almost all fields of work, and especially in engineering sciences where the technological trends rapidly develop (Guest, 2006). This type of lifelong learning also opens up our universities to a new type of students, that is students which already have an undergraduate degree but are looking to either up-skill or re-skill themselves. But courses aimed for lifelong learning also requires new ways of thinking in regard to the participants backgrounds, previous experiences, the applied pedagogics, didactics, and overall course design (Field, 2000). In which Networked learning (Gourlay, et al., 2021) and the research within is one key aspects for this to be successful in the long term (Goodyear, et al., 2004).

This article will present our work on this in the project IoT Professionals (IPROF) project that has been funded by the Swedish Knowledge Foundation's Graduate Professional Development program, which is a program that finances advanced level education for working professionals. As an effort to give universities support to give courses aimed for lifelong learning of currently working individuals. Within the project, we have chosen to focus on courses in typical computer and electrical engineering domains under fast evolution, namely the Internet of Things (IoT), Industrial IoT (IIoT), and machine learning (ML) domains, as well as related areas such as security. We chose this particular focus because of our research profile and cutting-edge expertise in these, and because of our large number of researchers in the areas. As well as it is where we have found the need for lifelong learning to be the most needed by our research partners.

The ambition of the project was to contribute to the industrial transformation using these new technologies and data-driven research and development to increase innovation, digitalization and strengthen the competitiveness of both the companies and the course participants. In this, we joined forces with five partner companies in the project, in order to together form and develop specialized courses based on the industry's needs, demands, and the working conditions of the working professionals and their employers. This work also became extra important during the COVID-19 pandemic as a wave of layoffs and decreasing economy, created a more difficult labor market for engineers and computer/electro-technicians. Which is why the original two-year project also got extended with additional pandemic related funding, which enabled us to give even more courses than originally planned.

The problem and major challenge of this work was to develop an education and pedagogical model for giving courses to working professional engineers in the computer/electrical engineering domains. Including both the work to determine which specific topics we should focus on and which specific courses to give. As well as the creation of relevant course materials and the education work with giving these courses to working professionals and their unusual study situations. Including identification and overcoming many obstacles along the way, such as university administrative, pedagogical, and didactical challenges. However, we will focus on these two questions in this article:

1 Which are the most vital components in a networked lifelong learning model, specifically aimed for working engineers and their companies?
2 How can higher education courses for working engineers be pedagogically and didactically designed to support networked lifelong learning?

Based on the overall problem and these questions, we have chosen to focus this work on the teacher's perspective and using design-based research approaches (Barab & Squire, 2004). Design-based research was a good fit for this project, since it allowed us to focus on creating learnings from the development of useful tools and teaching methodologies. As well as enables us to include the contextual situation of our students in the research, as well as studying our lessons learnt in this teaching context. Our primary contribution in this article is therefore on our implemented model and course structure which is adapted for working professionals and our evaluation thereof. Including our reflections and plan for future courses within this concept and our refinement of the model. The remainder of this article is organized as follows: We start by presenting our approach and education model in detail. To then present our results from the model, followed by our learnings and reflections. Ending with our refined approach, future work, and conclusions.

Model

Early on, we decided to develop our model with the following leading keyword in mind:

- Need and trend-based education offerings
- Up-skilling and Re-skilling (Taylor et al., 2021)
- Micro-learning (Jomah et al., 2016) and flipped classroom (Lage et al., 2000)
- Flexibility both in time and place (Collis, 2002)
- Win-Win possibilities (Nørgård et al. 2019)

What these means for us, is that we started by inventorying the needs and trends of a number of partner companies to get an idea of which courses they think their employees should study in order to further their education, i.e., up-skilling or what they should focus on to reach new customers/opportunities i.e. re-skilling (Taylor et al., 2021). As well as creating opportunities for company-related project work and laboratory sessions that the professionals can see a double benefit from doing, both in the course and in their regular work situation (Fuller & Unwin, 2004). Another double benefit was that we could use these courses for promoting our own research and finding new industry partners, which was important for the longevity of the courses. The pedagogy was inspired by microlearning (Jomah et al., 2016) and flipped classroom (Lage et al., 2000). Meaning that we offered small portion sizes in our courses, divided so you can take part of the parts you want, according to the need you have. And that the pedagogy and didactics in the courses are largely based on self-learning, information gathering, own laboratory work, to then discuss and present to each other. In even more concrete terms, the approach has been to create small courses at a low pace (3 ECTS credits in 10 weeks), completely on distance with high flexibility both in time and place (Dirckinck-Holmfeld, 2009). These courses were free of charge as all university courses are in Sweden (even for professionals) since they were given as a part of our regular course offerings. An overview of our order of work and work process in the model can be seen in Figure 1. Which gives details on the steps and milestones we have set up at our university that need to be taken in order to give each course. This process overview also highlights which of these steps that only need to be taken once upon course creation and which steps that need to be repeated for each time a course should be given.

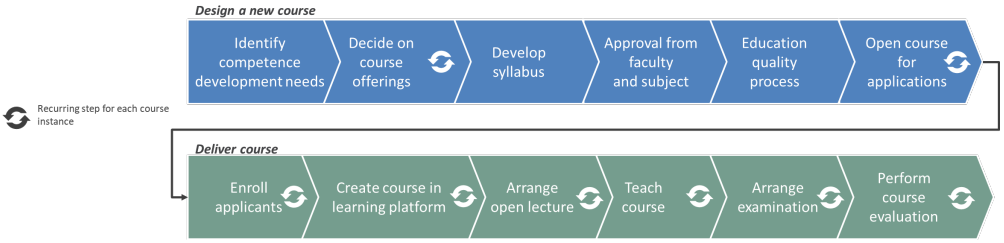

Figure 1. Our working process steps for each course

A more general and illustrative overview our education model and course execution from the educator's point of view can be seen in Figure 1. Which highlights the overall steps of inventory, development, course execution, and finally evaluation. This figure will be used as a guide for the remainder of this section, in which we will go deeper into each of these parts and explain them more in detail.

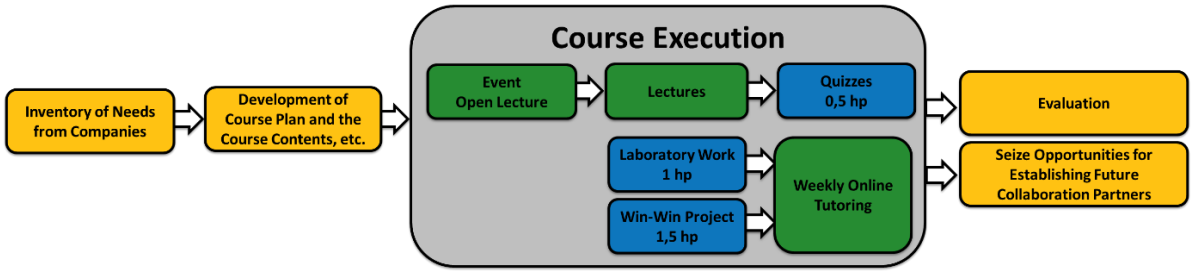

Figure 2: Overview of our general education model aimed at working professionals

Inventory and development

The work started with an inventory of the needs of the broad computer/electrical engineering industry. In which we interviewed our five closest partners within the project to get an overall view of their general needs. This was carried out with a series of interviews akin to semi-structured focus groups (Galletta, 2013), in which we discussed certain aspects of the upcoming courses. Both in form, the target group, their specific company needs, and the specific technological topics to focus on. After each interview, each company was given the task of creating their own wish-list of their most interesting topics that they think we should give our courses in. To help them in this work, we created an overview figure (see Figure 3) with a comprehensive list of potential technologies that are within our expertise area that we could fit within the project.

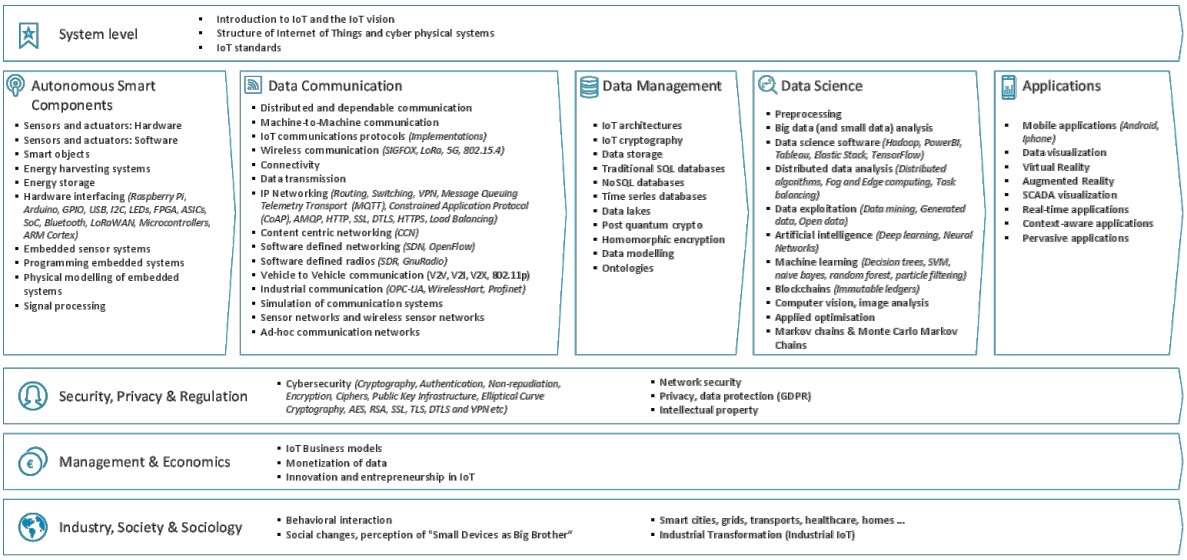

Figure 3: Technology list used in the inventory with industry partners

After the initial inventory with the industry partners, we had enough information to discuss and decide which courses we were to begin with. Once the decisions were made, we performed a series of workshops with the same partner companies to get their input for creating relevant expected learning outcomes, prerequisites, course contents, etc. for the syllabuses. The intended course responsible teachers led these workshops, which also included shortly presenting relevant background theory on Bloom's taxonomy (Bloom, 1956), the SOLO taxonomy (Biggs & Collis, 2014), constructive course alignment (Biggs, 1996) and the usage of the right verbs in syllabuses (Anderson et al., 2001), all in order to be able to get the most relevant feedback from the partner companies. After the workshops, the syllabuses were handed off to the university's internal syllabus quality review process, which has to have been carried out before the courses can be formally announced and given.

Course execution

Early on, we decided that these courses should not only be just for the formally enrolled students. We wanted to reach a larger audience and support lifelong learning for everyone and anyone that could interested in the topics of the courses. Even if they, for example, did not formally meet the course prerequisites of these advanced level courses. Therefore, we chose to start each course with a live-streamed open lecture that was open and freely available for anyone who wanted to learn more about the field. In this way, we also reached out to professionals who did not have time to take on a full course. We could also use this open lecture as a recruitment event to get more students to enroll. Since the course was open for late enrolment up to two weeks after the open lecture, and this open lecture was the first introductory lecture in the regular execution of the course. We also made a large effort in the marketing for this open lecture, sharing the event on all our social media channels, newsletters, to our research partners, etc.

In our education model, we chose to also stream the subsequent regular lectures and give them live, but not publicly. While at the same time record them so that the students who could not participate live still could take the course and take part in the material. Furthermore, in order to save on the teacher's time and resources each lecture also had an online quiz attached to it to ensure that the students had absorbed the material and so that they themselves could test their own understanding. In these quizzes, we applied a simple approach that forced the students to get all answers correct in order to pass, but they could retry as many times as they wanted without penalty. Most engineering courses also have practical laboratory sessions as an effective pedagogical tool to practice the student's engineering skills and techniques. But because the courses in our model were to be given on distance, these practical laboratory sessions had to be adapted so that they can run them on their own home or work computers without special equipment. All laboratory sessions were examined using oral presentations that were managed by screen-sharing, where the students showed their code and presented their work. Furthermore, all the lectures, quizzes, and laboratory sessions had to be encapsulated into suitable micro learning sizes for the working professionals to take on the tasks when it best fit their own work and life situations.

In order to support more networked learning aspects, we have also had weekly scheduled occasions where the teachers were available online for questions, presentation, and discussion about the laboratory tasks, as well as project supervision. These occasions were also used as opportunities for the students to discuss live and share experiences in the course, the laboratory sessions, and problems in their regular operations as working professionals. Each course also ended with a project assignment with case-based learning (Savery, 2015), where students had great freedom of choice, in the exact focus of their projects. All in order for them to be able to adapt the focus in their own learning to create win-win opportunities for themselves in their work and their lifelong learning.

Evaluation and future partners

Both during and especially after each course we had to evaluate the course contents, the level of the quiz questions, the laboratory tasks, and the overall progression within the course for the students. For the formative evaluations we had the weekly student meetings and course forums to reach the students and collect their feedback. But after the course, we both made short interviews with the students on their last session when they presented their final project, as well as a formal standardized written course evaluation form sent out to the students after each course has ended.

However, one especially important goal for us to give these courses was to establish new research partners, find new potential research projects, and find partners for future funding. Because of this, the teachers were given the task of collecting key information regarding the students work situation, their employers, and potential for future collaborations. This information was collected both in one of the first tasks the students were given, where they

should introduce themselves to each other, but also in the weekly discussion sessions. Finally, it was up to research leaders together with the particular teachers in each course, to take these potential new connections to the next level inside the research environment.

Results

As a whole we see our education model and the courses given as highly successful, since we have successfully passed over 25 working professional students using it. We have also managed to spread knowledge to a large audience beyond the enrolled students. Since we have had a substantial number of views at the open lectures, which have been shown an average of 300 times per lecture and course. However, some improvements in our model has been identified. When it comes to the courses themselves, we have had an average of 8 active participants per course. However, the throughput has been low, which we have analyzed and evaluated to be due to the fact that many professionals have been mostly interested in gaining relevant knowledge and getting access to good course material and not the ECDT credits per se. Which means that many have chosen not to complete the last project that involves report writing and oral presentation for grading and examination. But we can observe that the overall participation in the online quizzes, lectures, and laboratory sessions has been in line with other distance courses. Hence, we have determined that it primarily was the final project which lowered the student throughput. A list of all courses given with our model and their throughput can be seen in Table 1.

Table 1: Course listing and results

	Applicants	Participants	Passed
Applied machine learning (2020), 3 ECTS	150	28	5
Applied machine learning (2021), 3 ECTS	86	19	7
Internet of Things-protocols, 3 ECTS	59	6	2
5G technologies, 3 ECTS	46	6	1
Effects and strategies in IoT, 3 ECTS	42	22	12
Introduction to IoT-nodes, 3 ECTS	38	13	0
Applied network security, 3 ECTS	66	10	1

Another important aspect which was noted during the post course evaluations of these courses was the low conversion rate from applicants to enrolment. Meaning that out of the 487 applying students only 104 were actually enrolled later on the courses and started. Hence 383 students had their application invalidated either by not fulfilling the formal prerequisites or by themselves not actively accepting their enrolment once they were approved and had to formally agree to the enrolment.

Reflections and learnings

The cooperation with the partner companies was very fruitful and successful, especially in terms of gathering their competence development needs and discussing priorities with regards to the course offering. The courses were designed on their requests to be completely digital with no mandatory on-campus presence, which also worked very well during the COVID-19 pandemic. All lectures were recorded which created flexibility for the students and allowed them to view the lectures when suitable (Collis, 2002). In addition, the weekly sessions were scheduled so that students get live help from teachers, ask questions, and network learn from each other (Gourlay, et al., 2021). Some working students even asked for some evening time slots for tutoring, which we were able to fulfil as well. Because of these types of special circumstances, we have had many reflections and discussions on the need for finding teachers with the right competence to deliver these types of courses. A teacher in these courses for working professionals must for example be able to plan the course carefully and university leader functions need to make sure that the right teacher competence is available at the right time when the course is to be given. The digital format has required support to be available for less digitally experienced teachers and students. But as everyone gets more acquainted and comfortable with the digital format, which almost happened by force now during the COVID-19 pandemic, we expect the need for such support to decrease going forward.

After our initial course, several weaknesses in the internal administrative processes at our university were identified. Hence, we performed a workshop with all relevant personnel to identify improvement opportunities and to design a process for development and implementation of the courses. Which resulted in the process picture shown back in Figure 1. The workshop identified for example different internal obstacles, different ways to handle the inertia of the administrative system, and time constraints for new courses. Based on this discussion, a template was developed for gathering the necessary information that the administrative

functions need to set the correct dates and specific information regarding the courses in the administrative education systems. Hence, we believe that by following this new process, the amount of manual double checking by the project manager will also decrease going forward.

However, and as previously mentioned. The percentage of students that completed the courses was relatively low. Many of them attended the lectures and did most of the laboratory work but did not go the whole way and presented their work to the teachers. Hence, they did not receive all their ECTS credits, but they hopefully still had gained their desired knowledge which was the primary reason for them attending the course and their lifelong learning. However, we need to revisit the tasks and learning goals to make them better and more relevantly aligned (Biggs, 1996) for the situations of the working professionals. We could also see that the completion rate was higher when there were at least two people attending from the same company as they could work together and discuss the course among themselves at their workplace. Another learning is that oral presentations of the laboratory work were preferred over the written presentation as in the final project report. Finally, a very positive take-away from our implementation of the model was the arranged open lectures at the start of each course. They were particularly good opportunities to market the course by inviting people to take part in this first open lecture and well appreciated by many of our research partners.

Finally, one very important insight we had after giving all these courses was that we have identified two distinct types of courses. And these two types could be characterized based on the number of participants in each course, their different technological focuses, and their degree of co-production with the partner companies.

The first type of course in our model was the broad recruitment courses, which were created based on the broad needs of the industry and our partner companies. The course in applied machine learning was a typical example of this kind of course, where an entire industry is looking for more knowledge in the machine learning field right now. This type of broad courses given in an attractive area has the potential to recruit many students. We see that these courses are important for creating a critical mass in the project and that they provide an opportunity to find new contacts, new students, new collaborations, as well as to market our concept and the other subsequent courses. These courses meet the general needs of the business community and are strongly linked to our regular course catalogue.

The second type of courses were narrower in focus and more specialized profile courses, i.e. courses where we had research excellence. These courses can to some extent be seen as a continuation of the general broad courses, but with profiling towards our areas of expertise and strongly linked to the research within our research profile. A typical example is the course in 5G technologies that we have given within our model, which is strongly linked to our research center, research profile, and a specific research group. The co-production in these courses were higher and the courses themselves were more unique. Where we have been alone, or at least one of few high education institutions in Sweden who even have the knowledge to give these types of specific profile courses.

The future

We are currently working on refining our model and plan for future courses. See Figure 4 for an overview of our new educational concept. One of the primary insights for this future is that we will work more with the different categories of courses. Both the two previously identified types, the broad recruitment courses and narrower profile courses, as well as a completely new third type of course. Which will focus on even greater co-production.

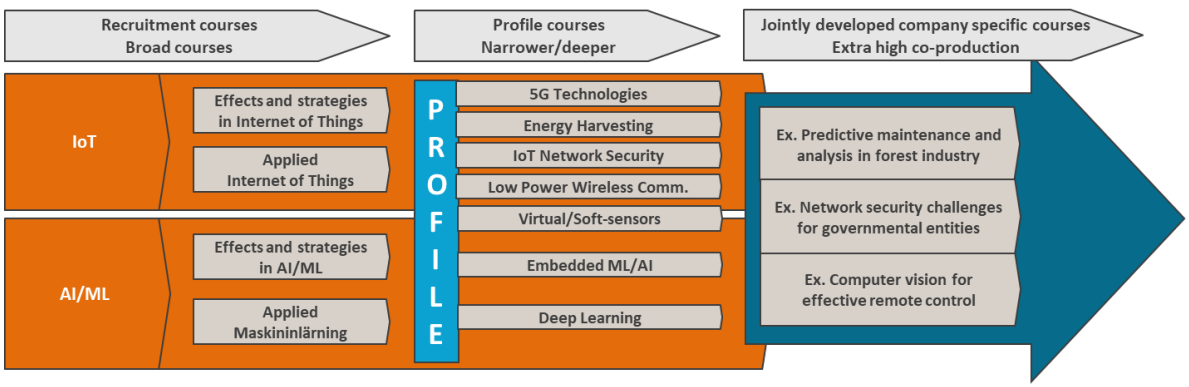

Figure 4: Overview of our general approach and execution for courses aimed at working professionals

We call this third type of course jointly developed company specific courses. In which we will have the deepest co-production, but with a specific company. The purpose of this is to create courses that really address a specific need of a company. But to create such a course will also require a great deal of work, problem analysis, and especially collaboration. We imagine that these courses will be like small joint research projects in course forms, where we together explore an area, learn from each other, work with companies' specific problems and work and apply knowledge from the research front. A form of networked learning between companies and the university. Where one of the goals of these courses is that they should lead to follow-up new research projects from other funders. An example of such a course could be a course in predictive maintenance in the forest industry, which then would be developed together in close collaboration with a company in the forest industry, for example SCA. Another example could be a course in computer vision for effective distance control of machinery, together with for example HIAB which is a company that develops hydraulic cranes.

We are currently working on acquiring funding to implement this next step, as well as a review of the courses didactics and pedagogics to investigate various possibilities and future avenues to explore in order to increase the throughput and increase the activity rate of the working professional students.

Conclusion

This article presented our model for giving courses to working professionals, in the technical domains of computer and electrical engineering. We presented the model itself, a detailed explanation of each part inside the model, our course execution, the student results from these courses, and finally some reflections and lessons learnt.

The first research question was related to which elements that are required for creating lifelong learning aimed for working engineers. We see these leading keywords as our means to address this research question and from which our whole model was created. These key words were: Need and trend-based education offerings, Up-skilling and Re-skilling, Micro-learning and flipped classroom, Flexibility both in time and place, and finally Win-Win possibilities. To these we then have set up a number of activities as parts of the model's implementation. See section Model for more details regarding the specifics around these.

The second research question was on how the pedagogics and didactics can be designed to support networked lifelong learning. Here we see that we have not come all the way to the end, as more work remains.
We have carefully thought and set up many of the activities in our model, including the open first lecture, the self-examining online quizzes, and the self-paced adapted laboratory work. As well as enabling the students to network learn through discussions among the working professionals. However, since the throughput of passed students were low, we need to rethink the final examinations in the courses. The working professionals did neither have the time nor ambition to pass the final part to get a final grade and course credits. Even if many of them did the practical work and gained the necessary skills. Hence, the tasks and learning goals must be better and more relevantly aligned for the situations of the working professionals.

We aim to continue this work during the next year by refining our concept and giving even more courses, as well as achieve even higher co-production with the new co-developed company-specific courses. All in order to enable and support lifelong learning of working professionals and working engineers in particular.

References

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., ... & Wittrock, M. C. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. White Plains, NY: Longman.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1–14.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*(3), 347–364.

Biggs, J. B., & Collis, K. F. (2014). *Evaluating the quality of learning: The SOLO taxonomy* (Structure of the Observed Learning Outcome). Academic Press.

Bloom, B. S. (1956). *Taxonomy of educational objectives*. New York: McKay.

Collis, B., & Moonen, J. (2002). Flexible learning in a digital world. *Open Learning: The Journal of Open, Distance and e-Learning, 17*(3), 217–230.

Dirckinck-Holmfeld, L., Jones, C., & Lindström, B. (2009). *Analysing networked learning practices in higher education and continuing professional development*. BRILL.
Field, J. (2000). *Lifelong learning and the new educational order*. Trentham.
Fuller, A., & Unwin, L. (2004). Expansive learning environments: integrating organizational and personal development. In *Workplace learning in context* (pp. 142–160). Routledge.
Galletta, A. (2013). *Mastering the semi-structured interview and beyond*. New York University Press.
Goodyear, P., Banks, S., Hodgson, V., & McConnell, D. (2004). Research on networked learning: An overview. *Advances in research on networked learning*, 1-9. Springer.
Gourlay, L., Rodríguez-Illera, J. L., Barberà, E., Bali, M., Gachago, D., Pallitt, N., ... & Knox, J. (2021). Networked learning in 2021: A community definition. *Postdigital Science and Education, 3*(2), 326–369.
Guest, G. (2006). Lifelong learning for engineers: A global perspective. *European Journal of Engineering Education, 31*(3), 273–281.
Jomah, O., Masoud, A. K., Kishore, X. P., & Aurelia, S. (2016). Micro learning: A modernized education system. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 7*(1), 103–110.
Lage, M. J., Platt, G. J., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *The journal of Economic Education, 31*(1), 30–43.
Nørgård, R. T., Mor, Y., & Bengtsen, S. S. (2019). Networked learning in, for, and with the world. In *Networked Professional Learning* (pp. 71-88). Springer, Cham.
Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows, 9(2), 5-15.
Taylor, A., Green, A., & Hassan, S. (2021). Priorities for up-skilling and re-skilling: What role can and should universities play?. WMREDI, University of Birmingham.