WIP: Lifelong Learning in Electrical Engineering: Courses to Support Professional Competence Development in Electrification in Transportation- and Aviation Sectors

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***Abstract*— This innovative practice WIP paper describes the ongoing development of lifelong learning education in electrical engineering. There is a transition in society and industry towards more electrification of the transportation sector, requiring new knowledge. Three lifelong learning courses on electrification of the transportation sector at Uppsala University are described. The courses consist of an introductory course on electric vehicles, a more technically advanced course on electric vehicles and charging systems, and a course under development on electric aviation. The work is ongoing, and the method includes analyzing the course syllabus, the views from summative course evaluations, and the views from a teacher in the course. The preliminary results include opportunities and challenges identified when developing lifelong learning courses. From the preliminary results of this work in progress, it is concluded that the learners appreciate the courses and take an active part in the classes, but that the reasons for participating in a lifelong learning course vary. Specifically, the learners might not be interested in gaining a high grade on, or even passing, the final exam, but rather interested to gain personal knowledge from the classes. The lifelong learner may need enhanced flexibility in terms of scheduling, and the teacher needs to be able to adapt the content of the course to the participants' wide range of backgrounds. It is concluded that lifelong learning in electrical engineering could be particularly interesting due to the rapid changes in industry and society towards enhanced electrification.**

Keywords—electrical engineering, lifelong learning, metacognition.

I. Introduction

This innovative practice WIP paper describes the development of lifelong learning courses in electrical engineering. Recently established national educational goals aim to provide university courses for continuing education for professionals [1]. These 'lifelong learning' courses aim to support industry and society with relevant knowledge to meet and further strengthen the ongoing transitions to a more sustainable society. This, in turn, concerns for example, the electrification in the transportation- and aviation sectors. The transportation sector is undergoing a change towards electrification, giving rise to the specific need to reskill engineers to be able to work with electrical propulsion systems. Moreover, there is a great societal interest in electrification, limiting pollution from the transportation sector, and learning about new electric vehicles and charging systems. There has also been an interest from society and industry to collaborate with academia in disseminating knowledge in electromobility, resulting in the development of collaborative and interdisciplinary courses.

Several new courses for lifelong learning were developed at Uppsala University to meet the needs of industry and society. Courses were being developed in the area of electrification of the transportation sector and designed to be given in a mainly online format. At the Department of Electrical Engineering at Uppsala University, several lifelong learning courses are provided, such as the courses 'Introduction to Electric Vehicles', 'The Electric Power System and the Electromechanical Propulsion System in Electric Vehicles', and 'Electric Passenger Aircraft'. The main research questions addressed in this ongoing project are: (1) What are the opportunities and challenges of designing and delivering lifelong learning courses in the field of electrical engineering to meet the transition of electrification in the transportation sector? (2) What can colleagues at other universities take away from Uppsala University's experience with lifelong learning courses?

II. Background

The lifelong learning courses at Uppsala University are developed for learners interested in changing careers, enhancing personal development, enhancing professional development in general, or meeting a more specified need of the employer to gain more or new knowledge in a certain area relevant to the industry [1]. Lifelong learning focuses on education that can occur continuously throughout life, as we meet changes for example in our work [2]. Lifelong learning in engineering relates to the literature on e.g., strategies to support students in becoming self-directed learners [3]. Learning about one's learning strategies is known as metacognition [4], which relates to becoming a lifelong learner. Learners who are aware of their learning strategy and monitor their learning are often successful as learners throughout their lives. As such, metacognition often

relates to success in self-directed learning and lifelong learning. The students should be empowered to continue to learn new things actively, and in a self-directed way, to meet the new challenges in society [5]. In [6], the authors analyze and evaluate useful strategies to become lifelong and self-directed learners among first-year engineering students. Self-directed learning was analyzed and monitored in [7], for mechanical engineering education to support the students in becoming lifelong learners. The research on lifelong learning and continuous learning has been addressed in the context of different professional engineering tasks used in the industry, such as support for staff in learning to use new software more effectively [8].

III. The Innovative Practice

The uniqueness of this practice is the connection between lifelong learning course development and rapid changes in society related to electrification. The innovative practices described in this paper build on literature relating to lifelong learning [2], metacognition [4], and strategies to support students in becoming self-directed learners [3], yet differ in terms of the focus on electrification of the transportation sector.

The pedagogic development is based on recent scientific research and development in the field of electrified transportation systems, including analysis of new charging strategies for electric vehicles [9], and new types of electric vehicles such as electric aircraft and charging at airports [10]. It is innovative as it describes education for lifelong learning in areas where the electrification is highly novel and innovative, such as the electrification in the aviation sector. Learning new things throughout one's work life is useful in the engineering field, where new innovations and new methods continuously require staff to have new and updated knowledge in their technical field. The recent changes in engineering, such as new goals towards electrification and sustainable development, digitalization, varying geopolitical aspects on supply chains, innovations, security, and other global events, such as the COVID-19 pandemic, all suggest that lifelong learning courses are useful, not least in the engineering field. Being prepared for new and changing aspects also relates to resilience, and both energy- and transportation systems need to be resilient, as well as the engineers working with the systems. In this context, the newly designed lifelong learning courses and similar education are important to meet rapid change in society.

IV. Method

The methodology of this work in progress paper includes analysis of data collected from students using summative course evaluations, information from the course curricula, and data from teachers using interviews. The work is currently ongoing, and the results are so far preliminary. The lifelong learning courses for electrified transportation systems developed at the Department of Electrical Engineering, at Uppsala University are being investigated. The courses are mainly given online with the use of Zoom and an online learning platform. The ongoing pedagogic development includes a team of several teachers. The educational development benefits from the research in the electrification of the transportation sector.

V. Preliminary Results

The course content and the course-specific challenges and opportunities of the three courses are summarized in Table 1, and the initial results from the summative course evaluations in 2023 are summarized in Table 2. This is a work in progress, discussing initial initiatives to analyze the development of new lifelong learning courses.

A. Introduction to Electric Vehicles

The course 'Introduction to Electric Vehicles', 5 credits, provides an introduction to the main aspects of electric vehicles and charging infrastructure in society. The content of the course is summarized in Table 1.

TABLE I. Three lifelong learning courses in electrical engineering at Uppsala University

Details	**Preliminary results from lifelong learning courses based on teacher interviews**		
	Introduction to Electric Vehicles	***The Electric Power System and the Electromechanical Propulsion System in Electric Vehicles***	***Electric Passenger Aircraft***
Credits	5 credits*	7.5 credits*	5 credits*
Course content	Introduction to electric vehicles and charging strategies, analysis of different electric cars, an overview of the propulsion system, and sustainability aspects. Student presentations on an electric car and multiple-choice exam.	Technical aspects of the propulsion system and charging of electric vehicles. Power electronics and the electric motor. Theory in Maxwell's equation. Student presentations on different types of electric vehicles and a multiple-choice exam.	Introduction to electric aircraft for passenger flight and electrification at airports, including relevant charging infrastructure, local electricity production, and energy storage. The course is currently being designed, to be given for the first time in the autumn semester of 2024.
Course-specific opportunities for the teachers	Benefit from the large pre-knowledge and background from learners with experiences from working in engineering industries or owning electric vehicles. This creates interesting discussions. Students learn from each other.	Genuinely interested learners with various backgrounds, often from engineering industry work. Interesting questions from the learners and good discussions on the topic.	In the design phase. Provide a new course in a highly innovative and new area (i.e., electric aviation). Create discussions on lifelong learning in new areas where technology is changing rapidly, for example, to meet sustainability goals.
Course-specific challenges for the teachers	To (a) introduce learners to the learning platform and the online classroom, (b) ensure enough flexibility for learners working in industry, and (c) find a suitable content level based on the learners' pre-existing knowledge.	To teach learners outside academia about complex theories, such as Maxwell's equations, in easy ways and describe why it is relevant, for example, to understand electric motors in vehicles. To motivate the students to take the exam and course evaluation, not only go to classes.	To design a course (a) in an area where there is rapid ongoing innovation and development, and (b) for learners with no recent experience of academic studies. To create room for discussions and flexibility based on the learner's interest, while keeping a focus on the syllabus and recent research.

* 1,5 credit equals 1 week/40 hours of full-time study.

Goals of the course includes to describe e.g., an overview of the technical systems electric vehicles and the development of the future electric grid to meet the needs of more electric vehicles, and to present the opportunities and challenges of electric vehicles from different sustainability perspectives [11].

Each student does a small project about an electric vehicle of their choice and gives an oral presentation in the course. The introductory course ends with an exam featuring 30 multiple-choice questions. Most students who have followed the course from start to end pass the final exam. The results from the summative course evaluation in 2023 showed that the students thought that the course was quite good, with a mean value 4.5 on a 5-grade scale where 5 was Very good, as shown in Table 2. However, the number of students responding was low. The experience of a teacher is that the students are curious and have a significant variation in their background and reason for studying the course; some learners are professionals with an interest in electric vehicles, some are enthusiast owners of electric vehicles, and some are interested in preparing for other studies at university levels, such as preparing for an engineering program. All learners contribute to the learning environment.

B. The Electric Power System and the Electromechanical Propulsion System in Electric Vehicles

The second lifelong learning course about electric transportation is a more technical course titled: 'The Electric Power System and the Electromechanical Propulsion System in Electric Vehicles' with 7.5 credits [12]. As presented in the syllabus and summarized in Table 1, the goals of the course are to describe, for example, the electric grid and charging of electric vehicles, the technical components of the propulsion systems, important economic aspects of electric vehicle design and use, and to work with an individual project. The final exam includes 30 multiple-choice questions. The course provides a deeper understanding of the technical components of the electric vehicle, including lectures and guest lectures on e.g., the electric motor, the charging system, Maxwell's equations, and power electronics. The initial results from the summative course evaluation 2023, summarized in Table 2, show that the general student opinion about the course is very positive and that the level of difficulty and requirements was just right, however, there was low participation in the course evaluation. The experience of a teacher is that the learners are very interested in the course and eager to engage in discussions about its topics. However, not all learners are equally interested in taking part in the exam and course evaluations. Takeaways for teachers from the course relate to motivating lifelong learners to not only study electrical engineering applications but also to learn about the theory behind them and why it could be important or interesting to learn more about electromagnetism.

C. Electric Passenger Aircraft

The aviation sector has been in specific focus when it comes to pollution from transportation and there is a significant interest in changing the propulsion system of aircraft to for example electric, hybrid, or hydrogen. The course 'Electric Passenger Aircraft', 5 credits, will be given for the first time in the autumn of 2024, and the course is currently in the design phase [13], as highlighted in Table 1. The syllabus describes that the goals are e.g., to learn about the technical systems of electric passenger aircraft, about sustainability aspects, to provide an overview of technical components, to understand charging strategies at airports, and to present the state of the art when it comes to electric aviation. The lifelong learning course will include an overview of the recent research and development in the electric aircraft industry and concerns charging infrastructure at airports.

D. Active learning methods for online learning

The wide range of student backgrounds makes the active learning methods particularly useful in class. In the lifelong learning courses presented above, several easy-to-use online tools such as padlet.com were included to, for example, encourage students to compare the pros and cons of different types of electric vehicles. Also, the tool menti.com was used to ask the audience at the beginning of the lecture what they think about the topic of today's lecture and to create a word cloud of their thoughts. When using these tools, keeping the questions asked to the audience rather easy in the beginning helped the students to be comfortable enough to answer the first questions in the online classroom and so get the discussion going.

TABLE II. THREE LIFELONG LEARNING COURSES IN ELECTRICAL ENGINEERING AT UPPSALA UNIVERSITY

Details	**Initial results from lifelong learning courses based on course evaluations in 2023**		
	Introduction to Electric Vehicles	***The Electric Power System and the Electromechanical Propulsion System in Electric Vehicles***	***Electric Passenger Aircraft***
My general opinion about the course is (1= Very bad, 5 = Very good)	Mean value: 4.5	Mean value: 5	Given for the first time in Fall 2024.
The difficulty of the course was (1 = Too low, 5 = Too high)	Mean value: 2.5	Mean value: 3	-
The work needed per credit was (1 = Too low, 5 = Too high)	Mean value: 2.5	Mean value: 3	-
My pre-knowledge was (1 = Insufficient, 5 = Sufficient)	Mean value: 5	Mean value: 5	-

One concrete example of an easy task to get the students comfortable in the online classroom is to show a figure of an electric car with text boxes on the different components, such as battery and electric motor, and to cover some of the text boxes and let the audience guess the component of the propulsion system. Furthermore, in Zoom, breakout rooms and whiteboards are useful to divide the learners into discussion groups. The larger room can then be used to compare the ideas of the different groups. The online learning platform could be useful when constructing formative and

summative assessments, such as the opportunity to design sets of self-corrected multiple-choice questions.

There are several examples of challenges and opportunities for teachers when it comes to implementing lifelong learning courses. This relates, for example, to the fact that the learners may not have been visiting the university or the learning platforms for quite some time. The reason for this is that the learners may work in industry currently. The teachers cannot assume that the learners are used to and informed about general university studies. The learners are also not used to filling out course evaluations in an online tool after the course with the exam is finalized. Therefore, there is an opportunity to learn about student views through future interviews or midterm evaluations. Moreover, they may take the course mainly for personal interest, rather than for gaining university credits, which in turn might cause lower participation in the exams than in the classes. The learners might also have a schedule at their workplace that prohibits them from taking full part in the course, especially if course materials and filmed lectures are not provided online.

On the other hand, the learners are often working with relevant areas in the engineering field and may have significant experience from electrification or transportation systems which is highly valuable for the learning environment. The following challenges and opportunities may present themselves in the lifelong learning classroom:

- explaining the university system and educational platforms used to students who are not familiar with today's academic education,
- teaching about threshold expressions in electrical engineering in an easy way,
- taking advantage of the diverse experience of the student group,
- providing sufficient flexibility to meet the needs of working students,
- dealing with learners who are not interested in passing the course, only in learning,
- making the most of student-experts currently working in the same field of the course topic.

VI. Discussion

The take-home message for the audience attempts to inspire with new perspectives on how to teach lifelong learners in electrical engineering and to provide inspiration for active learning in the online classroom for a wide audience with an interest in electrification. Specific new ideas for the participants to take away from this paper include strategies and inspiration on how to build education for lifelong learning in electrical engineering. This includes some of the topics used for lifelong courses presented here, the pedagogic approaches and tools used, as well as the challenges and opportunities described and how these might help in creating lifelong learning courses or continuous education in other topics.

There are several possible limitations on the transferability of this work to other universities. The overall setup and goals of education for professionals can vary at different universities and in different countries. Also, the funding for participating in the courses can vary, and these courses are generally free for all citizens, meeting the educational requirements. The skillset needed to educate the workforce and other persons interested in society can also vary over time, with different societal needs and trends. The work is ongoing and the results from analyzing or developing the lifelong learning courses are at an initial stage. Therefore, there are potential limitations in how transferable the results from this paper are to teachers and educational staff in other parts of the world. There are also variations in the time provided for the teachers to develop and give new courses, and many teachers also work with research. In this case, the teachers work with research in the same fields as the courses, making it easier to design and implement a lifelong learning course while working with research.

VII. Conclusions

Designing new courses for lifelong learning includes new opportunities and challenges for the teachers involved. When the course starts, the level of the learners might vary significantly, and the learners often have different backgrounds and reasons for taking the course. As a teacher, you have to be flexible and open-minded to meet the views of the group, while facilitating learning in the electrical engineering field. The lifelong learning courses at Uppsala University included two courses on electric vehicles: one introductory course and one more technically advanced follow-up course, both appreciated by the learners and teachers. A new course is currently being designed on electric aviation, highlighting the societal and industrial interest in learning more about ongoing electrification in new areas, in this case electric aircraft and electrification at airports. The work discussed in this work in progress paper is currently ongoing, and the results are preliminary. The initial response to all three of these innovative courses has been very positive.

Future research in the field can include in-depth interviews with the learners to understand their motivation for taking part in a lifelong learning course in electrical engineering and the usefulness of the courses in their professional work. Also, future work will include the continuation of the course development with active learning methods online, especially the of the new course in Electric Passenger Aircraft. Furthermore, the interest in society and industry in new lifelong learning courses in electrical engineering will be investigated. In addition, more ongoing scientific research activities in electrification at our department will be included in the education.

The development of the lifelong learning courses In sustainable electrification at Uppsala University will continue. While definitely a new experience, the teachers are excited to be part of supporting lifelong learning and to contribute to knowledge-sharing among society, industry, and academia.

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