

WIP: Using the Case Methodology in the Electrical Engineering Classroom - the Example of a Course in Electric Aviation

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Abstract—This innovative practice WIP paper describes and exemplifies how the case methodology can be used in the electrical engineering classroom to teach about rapidly advancing technologies. The case method uses written descriptions of thought-provoking real-life professional challenges that students will try to understand and address through group work. This paper takes support from the educational research literature on the case method, problem-based learning, and on active learning methods. It contributes to these discussions with a focus on electrical engineering teaching as well as with a teaching case on the electrification of the aviation sector and the quickly changing technological challenges this entails. The uniqueness of this innovative practice concerns utilizing the case method in teaching electrical engineering in a particularly innovative field. The paper introduces the case methodology and how to author various kinds of teaching cases. A teaching case on electrification in the aviation industry will be outlined and evaluated in terms of discussing the teacher's view on teaching this case as well as how it was received and evaluated by students. The key takeaways from this paper are knowledge and encouragement for teachers to not only use the case method as a pedagogical tool to support students in thinking about innovative ideas at the forefront of electrical engineering - but also to start thinking about writing a case themselves.

Keywords—*electrical engineering, active learning, problem based learning*

I. INTRODUCTION

This innovative practice WIP paper describes how the case methodology can be used in the electrical engineering classroom. There is an ongoing shift towards electrification in the transportation sector. Engineering education should prepare students for new ways of working in fast-changing times, with constantly new technologies and innovations. Students should be prepared to work in organizations e.g., as future engineering leaders [1] or entrepreneurs, facing continuously new challenges while being prepared for both success and failure [2]. The students need to be prepared to be flexible to gain new knowledge when needed [3] and keep up with fast-changing technologies. The research questions addressed in this ongoing project are: (1) What are the main challenges and opportunities when designing and implementing the case methodology in electrical engineering education to analyze electrification of the transportation sector?, and (2) What can other educators learn from the ongoing work in using the case methodology in a course on electric aviation at Uppsala University?

II. THE INNOVATIVE PRACTICE

The uniqueness of the innovative practice includes using the case methodology in the electrical engineering classroom, with a new case in an innovative field. The uniqueness lies in showing the usefulness of the case method when teaching in technologically fast-developing fields, such as electric aviation, as part of the course 'Electric Operation of Aircraft, Drones and Helicopters' at Uppsala University in 2023. In the following pages an introduction to the case method, including different kinds of cases and the importance of emphasizing their benefits to students are outlined. So are examples from a case on electric aviation and tips on how to write and how to teach such a case.

III. INTRODUCING THE CASE METHODOLOGY

The case methodology involves written accounts of relevant and challenging real-life situations that the students are supposed to solve together in groups. Case methodology is commonly used for example in business studies or law [4], [5], [6], but also sometimes in engineering [7]. This paper takes support from the educational research literature on the case method, problem-based learning, as well as on active learning methods [4], [5], [6], [7]. The case methodology could be utilized to practice and prepare for real-life challenges and enhance skills in problem-solving [8]. Ongoing changes and innovations in the industry, such as electrification and digitalization in the aviation sector, require skilled personnel, flexibility, and a curiosity to learn and relearn continuously.

The case method is especially useful in engineering classes where the problems addressed are multifaceted and lack a single right answer [9]. Education research on the case method suggests that engineering students find this approach both fun, motivating, and practically relevant by situating their education in a real-life professional context [10]. As such, the research findings on the effectiveness of using the case method in the engineering classroom mainly concerns student engagement and enthusiasm [11], and conceptual understanding [12], [13], as compared to learning outcomes such as exam results [14], [15]. The case methodology could be used to learn about new challenges and opportunities that come with electrification and digitalization. The case method was e.g., previously used for this purpose [16], where the authors propose a learning case for the students to gain an understanding about cybersecurity.

Cases all illustrate a situation to be understood and analyzed by the students. The case needs to contain information important to the intended learning goals, but also enough of a story to make it come across as a real-world case. There are different kinds of cases that share many similar characteristics, but that also have different purposes. Illustrative cases serve to describe a problem in a real-world context for the purpose of helping students understand the bigger picture in which smaller challenges and decisions are part. Historical cases allow students to discuss why certain decisions were made and what other decisions could have been made instead, as well as why. Unfinished cases require the class to make qualified guesses regarding information that is not in the case and thereby get to exercise their judgment and draw on their knowledge from the course. Decision cases put the students in the shoes of a protagonist facing one or several important decisions. In this, most common, type of case there are single-decision cases (where a single, difficult, decision needs to be made) or multiple-decision cases (where one decision may affect another). Many cases combine several such types of cases for the sake of achieving both illustration of a problem in context along with a decision to be made taking this context into account. When writing a case, it is best to have a focused goal and achieve that effectively with as short a case as possible, than allow a case to become unwieldy and confusing due to length and multiple, unconnected, goals. In our case, we focus on how the shift from jet- to electrical propulsion of aircraft can be viewed from different perspectives.

A. Student benefits from cases

It is of great importance that students understand the purpose of case teaching and learning to feel motivated to benefit from the class. The teacher can before the start of the class explain the purpose of the session to the students. In doing so, the teacher can emphasize that the case discussion will help them practice, for example, differentiating between key and non-key information regarding a situation or decision, spotting the challenges presented in the case along with important contextual variables to keep in mind, come up with and analyze a few feasible solutions or decisions, argue for a certain decision or plan of action, and analyze possible challenges to the implementation of the decision made. One strength of a good teaching case is that it can resemble a real-world professional dilemma, and thereby can help students to prepare for their

future work. This is usually a great source of motivation for students, as is focusing on exciting technologies, companies, or challenges when writing or choosing your case.

IV. INNOVATIVE PRACTICE AND PREVIOUS LITERATURE

This paper builds on literature on educational research on the case methodology, problem-based learning, and active learning methods [4], [5], [6], [7], but it differs in terms of describing electrical engineering education and a case on the rapid innovation characterizing the electrification of the aviation sector. Ongoing research in the field includes e.g., [17] and [18]. The target disciplines are students interested in innovation and technical development at the master's level. Different courses could be supported by using the case method for innovations.

A. The context in which the innovative practice is applied

The students have Bachelor's degrees in electrical engineering and study the Master's Programme in All-Electric Propulsion Systems. The course is given in year 2 of the program, with the case in the second half of the course to build on the first-half's content. Another active learning method used in the program is group-based experimental work in an electrical engineering lab. This method allows students to discuss, collaborate, and learn from others. Compared to the case method, it has a deeper technical focus, a more technical way of working, and fewer possible solutions to problems faced. Cases, in turn, are comparably more related to soft skills, innovation, and students' future work in firms. Cases leads to a different analytical way of working, taking also non-technical aspects into account, which leads to more possible solutions, making it a good complement to the group lab work. No preparation was required for the case session, all instructions were provided in class, and the class room had movable tables. It was mandatory but not marked, since we did not wish to stress students as they were unused to the case format. Assessment could be included in the future by, for example, using short individual hand-ins.

V. THE ELECTRIC AVIATION CASE

This decision-type teaching case is meant to situate the course focus on electric aviation in the wider engineering context of the fictitious company Beller Aviation. Table 1 presents text from the case alongside the aims of that text.

TABLE I. PARTS OF THE TEXT OF THE CASE IN THE COURSE ARE PRESENTED TOGETHER WITH A DESCRIPTION OF THEIR PURPOSES

	<i>Case text (examples)</i>	<i>Purpose of texts / Teaching guide</i>
Part 1	Beller Aviation is a family-owned company (third generation) in the aviation sector. Beller is a global actor, designing, manufacturing, maintaining and selling aircraft for personal transportation worldwide. The company is founded in the US and has over 120 000 employees, and it is one of the larger companies in the aviation industry.	To put the company in a context with regards to (1) ownership, (2) degree of internationalization, (3) products, (4) industries, (5) country of origin, and (6) size in both absolute terms as well as relative to their competitors in the industry.
Part 2	Their planes are designed for jet fuel. From the owners, there is an interest in reducing the pollution from their aviation systems and becoming more environmentally friendly in the coming 5-10 years. Beller wants to play an active role in the future of aviation. The electrification of the car industry is highly influential on their thinking.	Here is some more detail on their products, their propulsion, as well as what priorities are guiding the development of next-generation products in the company.
Part 3	The company board has started to look at electric aircraft, hybrid aircraft and eVTOLs (electric vertical take-off and landing) as well as charging systems and airport development for future aircraft. But they are confused. The board is uncertain about what strategy to adopt when it comes to electrification. Moreover, the company engineers have expertise in jet fuel systems, not electric propulsion. There are also uncertainties in the board when it comes to competition from other companies (both new and old competitors). The challenges are technical, but also economic. If the new technical development would be very costly, staff may need to be fired.	Here the students get insights into the technology alternatives for future development considered by the company as well as their confusion about in which direction to go. The electrical engineering students can use their knowledge of electrification in the transportation sector to understand the challenges facing the company. This text moreover outlines some of the strengths and weaknesses of the company as well as what risks are involved in choosing the future technological path to take.

	<i>Case text (examples)</i>	<i>Purpose of texts / Teaching guide</i>
Part 4	In order to find a strategy forward regarding electrification, Beller Aviation has recruited a team of experts in electric aviation (you!) to present to the board: (1) A strategy forward on electrification and reduction of the pollution from the company products. (2) A SWOT analysis for the company on electrification and reduction of the pollution from the company products.	In this section, the students get specific questions to discuss based on their knowledge and on the information they have received in the case. They are also given a context of presenting their conclusions to the company board to help the students focus their advice in a short and clear presentation.

The firm in question is an industry leader in jet passenger aircraft and is facing a potential paradigm shift when it comes to aircraft propulsion technology. This shift concerns the rise of electric and hybrid-electric aviation, and the case revolves around what such a technology shift will mean for the company.

A. Purpose of the case

The purpose of the case is to provide students of the electrical engineering course with a focus around which to engage in discussions on the pros and cons of different engineering solutions, both from a technical standpoint and from the perspective of the company and its products as a whole. The case was not an examination, but supported the oral examination of individual work and written exam including both calculations and analytical discussions, by allowing the students to practice expressing themselves both orally and in writing. The identified purpose of the text sections presented in Table 1 above could be useful for the teacher when supporting the students in discussing the case in the classroom and to serve as inspiration for in-depth questions. Table 1 also serves as a template for how this kind of case can be written. For example, a similarly structured case could be written by changing the case text to concern another firm in another industry, while still serving the same purposes.

B. Use of helpful tools such as the SWOT analysis

The group discussion can be supported by using analytical frameworks, such as the so-called SWOT framework used when teaching the Electric Aviation case presented here. The acronym represents the words Strengths, Weaknesses, Opportunities, and Threats. Each word is then supposed to trigger discussion on, for example, “What are the strengths of the product development organization?”. Having a framework may guide the students’ group discussion and prevent it from going off on sidetracks. It also helps students discuss the questions from several angles.

C. How the case session was taught

This particular 45-minute case session starts with forming groups and presenting them with the structure of the session. This structure contains the main steps of forming groups, presenting the case, providing the short case to electrical engineering students to read through (the longer the case, the more appropriate to provide it to the student on beforehand to read before coming to class), reading the case (if applicable), discussion of case and case questions, producing a presentation to the company board, and finally making short presentations in front of the class or have a teacher-led discussion of the questions one-by-one using the student groups for input and the whiteboard to organize answers. It is useful for the teacher to use the last 5 minutes of the class to recapitulate the purpose of the class, what was done, and what was learnt. The teacher can also mention a few high-level takeaways for the electrical engineering students, such as the connection between product development and company strategy, or the importance of being flexible enough as an organization to walk back earlier decisions if they turn out to be wrong, or perhaps no longer right.

VI. PRELIMINARY RESULTS

The teacher's views on using the case in the classroom are presented in Table 2. Responses from students on using the case methodology in the electric aviation course are exemplified in Table 3. The teacher finds that the impact of the case methodology on the course has been beneficial in activating students, making them engage, and to situate engineering problems in a product and company context. Students’ attitudes toward using such a case are overall very positive, while they also acknowledge that using cases is new to them and their class mates, making it a bit of challenge. However, they much appreciated the chance to apply their knowledge to a “real life” problem, as well as the discussions this prompted with class mates. They also liked the focus of the electrification of aviation.

TABLE II. PRELIMINARY RESULTS FROM THE TEACHER EXPERIENCE OF TEACHING A CASE ON ELECTRIC AVIATION.

<i>Questions</i>	<i>Examples of teacher responses</i>
1. What did you think of teaching using this case for the course “Electric Operation of Aircraft, Drones and Helicopters”?	“This was the first time I used a case as a teacher in the engineering field. I think it was a very good way to engage the students in discussions regarding the concepts and complexity of the study area. The cases are good to prepare the students for future work in industry, and to highlight that the engineering perspectives might not only consider technical aspects.” “I noticed that many students liked and were engaged by the case and the tasks their group was given in solving it.”
2. What do you think are the opportunities and challenges in using the case methodology in your educational program?	“One challenge is to ensure that the students in the electrical engineering field are actively engaged in analyzing the cases, even if they are not used to working with the case methodology before. The lack of experience in using the case methodology in engineering education is also a challenge for the teacher, both when constructing new cases and when using the cases in the classroom. There are good opportunities for teachers to be more educated in the case methodology. For the learning experience, the cases could be useful to support active learning in the engineering classroom and to use the concepts introduced in the education in a more realistic future situation, to prepare the students for the work life.” “Also, I think the case and group discussion format is easier for some students to feel comfortable with. For others it will take more time.”

VII. DISCUSSION

The research literature [4], [5], [6], [7] on problem-based learning, the case methodology, and active learning methods support the views of the student and the teacher presented in Table 2 and Table 3, that such active learning methods, as the case methodology, could create useful in-depth discussions among the active students and support their deeper learning and understanding. The case methodology is often used mainly in other educational areas, as highlighted in the literature, to enhance knowledge among students, and there could be interesting opportunities to use the case methodology more in the electrical engineering field as well. Analyzing and utilizing the case methodology, and how to develop new cases for future innovation, is believed to be of interest to the conference participants. Also, the conference theme is highly present in the paper topic, as it discusses how to use the case methodology as a new way to embrace challenges and transform engineering education. Following the presentation of this paper, the conference participants will be encouraged to write a short teaching case of their own and try it out in their engineering or computing classroom. The case method could be useful for other teachers in their courses with complex challenges for engineering or computing education (e.g., in cybersecurity, sustainability, alternative energy sources, or the need for critical raw materials). The main takeaway from this presentation for the audience is to inspire and provide insights for the teachers to utilize the case method as a pedagogical tool when teaching about rapidly advancing technologies. The current piloting of this innovative practice is situated in the particular, but not unique, context of electric aviation. This context is at the moment particularly novel as new challenges and solutions are surfacing continuously. So, while the case method has proven both useful and appreciated by faculty and students alike, this might change as the field of electric aviation matures and the uncertainty currently characterizing innovation in this area subsides. The practice can be seen as transferrable to other engineering topics that are characterized by rapid change and innovation. We believe that cases can also be used to discuss other topics in the engineering or computing classroom.

VIII. CONCLUSIONS

A new fictive case on electrification in the aviation sector was used in the course Electric Operation of Aircraft, Drones and Helicopters at Uppsala University in 2023. The case

encourages students to analyze and discuss complex situations, in this case when a large company is interested in investing in future electric- and hybrid aircraft, and the students are encouraged to take on the role as expert advisors. The opportunities of this approach as suggested by feedback from students and the teacher in this new course are that the use of the case was appreciated in that it highlighted how engineering decisions are connected to a wider company context. It was moreover found to be a good way to make students feel engaged. The teacher was pleased with this case-method pilot. The students seemed satisfied, and all students passed the discussion and analysis part of the exam. They were generally excited by the discussions of the case. Challenges were for the teacher to learn how to teach the case, for students to get used to analyzing the case, to make the case authentic enough to be engaging for all students, and to find the right balance between specificity and generalizability beyond the specific context of the case. This last aspect is important as all cases are unique, but they also have things in common, which makes parts of the learning possible to generalize to other engineering situations. What other educators can learn from this study is that when using cases in the electrical engineering classroom are to make sure there are clear links between the case and the knowledge students have acquired in other learning activities so that this knowledge can be drawn upon in the case discussion. This will help students in discussing the case and make them feel more comfortable. It was noted that both teaching and learning with cases may require some experience before feeling natural. It is concluded that the case methodology is appreciated by both students and teachers, and useful for educators in the engineering field to support the students in learning about complex aspects relevant to the future work as engineers. We hope that this case at Uppsala University can serve as inspiration for other engineering courses.

Developing the case teaching in electrical engineering further, we will draw on what we have learned about the capabilities and limitations of the case used. We will work on making the case more authentic, perhaps by using a specific real-life aircraft manufacturer instead of a fictitious one. We must keep in mind how to support both teachers and students in using the case, as this practice is still quite new at the Department of Electrical Engineering. Tying the case closer to other readings in the course will help facilitate the case discussion and hopefully provide more confidence for group discussion.

TABLE III. PRELIMINARY RESULTS FROM STUDENT EXPERIENCES IN LEARNING FROM A CASE ON ELECTRIC AVIATION.

<i>Questions</i>	<i>Examples of student responses</i>
1. What did you think about the case used in the course "Electric Operation of Aircraft, Drones and Helicopters"? (Please see the case in attachment. Was it good, bad, interesting, etc.?)	"I think using the case is a really good way to further the study. The example in the attachment combines both the concepts of electric aviation and the SWOT analysis which I learned from another course Industry Project Management that really inspired me to use the available tools to analyze this new field of electrification. The case of Visby airport is more interesting. I was able to feel more authentically that some of the concepts in the book are becoming part of reality." "That case study was really interesting. It got me thinking about how the aviation industry can become more eco-friendly by using electric power instead of traditional fuel. The case showed challenges the company faces and their goals for the future, which initiated some good discussions in class. Also, it helps us to understand real-world problems and how to solve them."
2. What do you think are the opportunities and challenges in using the case methodology in your educational program?	"Opportunities are the strong link between theory and reality and multidisciplinary interpretations. On the other hand, if a case is too specific then will lose its generalization. Or sometimes just don't have a good example to show. In summary, I would say I pretty like the way of using cases in the course." "In my opinion, Students get a chance to apply their theoretical concepts gained from the course into practical situations, resulting in deep understanding of the subject. It also encourages students to think critically, develop problem-solving skills and active participation in class discussions." "To find out good case studies and teaching them needs lots of time and effort from teachers. Sometimes, we all see a case in different ways, which can make discussions tricky." "Overall, though, I think it's a valuable way to learn."

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