

Using a case study as a learning vehicle in improving the learning outcomes of a course in SoSE Research Methods

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Abstract— In our master programs for industrial economy and systems engineering, we prepare students for their master’s project with a course in research methods. We concluded in 2020 that the course was too abstract without a running case. Following up on previous research, we report how we improved the intended learning outcomes by using a case study as a learning vehicle. The selected case study was on Technical leadership.

In this paper, we document and discuss how well we achieved the intended learning outcomes for the course. Main conclusion is that the running case needs more preparation to ensure that students can collect sufficient data for use in the course.

Keywords—learning outcomes, research methods, case study, technical leadership, data collection, systems of systems

I. INTRODUCTION

This course in research methods in systems of systems engineering (SoSE) is a pre-course for master students in Industrial Economy or Systems Engineering at the University of South-Eastern Norway (USN). When on schedule, they execute their research in the spring semester of 2021.

We ran the course for the second time during the fall semester of 2020, documenting our experiences in [1]. We identified these required improvements:

- Restructure the order of the topics in the course
- Including a running case in the course that teams in the class can work on during the course days.
- Unfreeze students even more from the paradigm of exercising well-known problems and solutions.
- Stimulate students to interact more with teachers, academic supervisors, and stakeholders.

We actively pursued these changes. In this paper, we focus on including a running case, which is the main pedagogic improvement. The purpose of this research is to evaluate the effectiveness of including such a running case in the research methods course. The goal of this paper is to share our experiences of using a running case in such course.

The organization of the paper is as follows: First, we present a recap on the course learning objectives and learning outcomes, and research framework taught in the course.

Second, we introduce the case study on Technical leadership, discussing its choice and intention, followed with the students’ view on the provided case study. Then we describe a side step on obtaining the data for research using a ‘dental case’. Lastly, we summarize the course evaluation and effectiveness before offering our conclusions and discussing future research.

II. DESCRIPTION OF THE COURSE RESEARCH METHODS

A. Objective and Learning outcomes

The main learning objectives designed for the research methods course in systems of systems engineering are as follows [1]:

- Enable students to clearly explain the line of reasoning for doing the research
- Enable students to formulate the research questions so that they can design and execute the research
- Teach students techniques for effective literature reviews
- Make students confident in research design.

At the end of the course, the students should have the following learning outcomes:

- be able to conduct research work in accordance with scientific standards and principles of research ethics
- can analyze, interpret, and critically assess the results available in scientific literature

B. Research framework

We used a 5-step (iterative) framework for carrying out the research. These steps include: (i) shaping the line-of-reasoning, (ii) exploring literature, (iii) determining the research design, (iv) executing the research project, and (v) consolidating and concluding. The 2020 publication [1] provides detailed descriptions for each step.

C. Systems-of-Systems topics

The students selected project topics related to Systems-of-Systems (SoS) such as, Energy (e.g. conceptual models for seasonal energy storage, solar business models, potential interaction models for energy trading and control), innovation and business (e.g. incubators), education (blended learning), and logistics (digitalization of documents).

D. Students performance in 2019 course

Table 1 presents the distribution of grades for students who participated in the research methods course for this course and their final project. Norwegian grades range from A (excellent) to F (failed). All students scored similar grades for the research methods course and in the master project; 5 students scored one step lower, 3 students improved their grade one step, and 4 students had the same grade.

Grade	Research Methods	Master project
A	5	3
B	4	6
C	2	2
D	1	1

Table 1: Frequency of grades of students for their submissions in 2019 course.

The number of students is too small to make any conclusive observations. One aspect that may trigger questions is that 4 of the 5 students with an A for Research Methods scored lower in their master project. Is this coincidence or is there some systemic issue?

E. Adaptations due to the Corona Situation

The course was running from August 2020 until December 2020. The measures for coping with the Corona situation in Norway were in that period relatively limited. This situation forced us to adopt the course format into a partially online course to limit traveling for students from outside Kongsberg.

We expected that the main challenges in online teaching would be in the interactive sessions, e.g. group work and plenary discussions. We did not expect significant problems in lecturing, except a challenge to keep students' attention. The restructuring of the course since last year did change the balance between lecturing and interaction further to interaction.

The first 2 days of the course were in Mid-August, when the Corona situation was still reasonably open in Norway. We used two classrooms instead of one classroom. As teachers, we varied in what classroom we presented. Effectively that meant that we had part of the students in the classroom with the presenting or leading teacher, part of the students in the next classroom, participating and watching via Zoom, and students remotely. We formed groups that were complete within one classroom or entirely online. During these two days, five students were remote and 17 in the classroom.

In Mid-September, the situation was somewhat stricter. On the first day in September, nine of the students were online and 12 in class. We therefore moved back into a single classroom. However, the next day, we had only six students in class. The last day in October, we ran the course entirely online.

III. RESULTS OF ADDING A RUNNING CASE

Kokkula et al. [1] reported that students found the process of establishing research question(s) confusing and unstructured. Further, they claimed that adding a running case would help to serve as a learning vehicle.

According to Yin, the case study approach increases in relevance if we try to explain some contemporary

circumstances, e.g., how and why some social phenomena work [2].

The main purpose of a running case is that groups of students can use that case to apply the in-class assignments to start learning the research methods theory. This theory covers the first three steps of the course framework:

- Shaping the line-of-reasoning
- Exploring the literature
- Determining the research design

The SoS nature of the research projects makes the line-of-reasoning and research design challenging. The research environment is open and uncontrolled, where any research topics is context dependent. A risk is that the line-of-reasoning is too open and vague. Another risk is that we will collect rather qualitative or context dependent data. The challenge for this course is how we help the students to learn to develop a feasible and working research design. Such research design is much more than collecting a large amount of data and statistically analyzing the data. Meaning that students need to understand when and how to use statistical techniques, and how to reason and communicate about the results and validity.

A. Leadership case study

We have been organizing a series of online webinars, called "Room with a Systems Engineering view" about digitalization. The fourth event in this series addressed "Leadership and Digitalization". The format of these events was that we collected information before and after the event via a pre- and post- survey. A research question within our research group triggered the selection of this topic for this event.

Given the focus of the industrial economy program at USN, which has the ambition to educate industrial leaders for the future, we saw a good match between this topic and the students in the research methods course. The leaders need to cope with complexity arising from various systems-of-systems in day-to-day life.

The pre-survey focused on the focus of technical and systems leaders in digitalization. We defined 2 dimensions that participants could rank:

- An axis from mission and vision to actual operation ([3] provides an extensive overview; our axis uses the terms known by the practitioners)
- The PESTEL (Political, Economic, Social, Technical, Environmental, Legal) axis [4]

The post-survey uses an INCOSE model for technical leaders [5] [6], with the following main behaviors:

- Holds the Vision;
- Thinks Strategically;
- Fosters Collaboration;
- Communicates Effectively;
- Enables others to be successful;
- Demonstrates Emotional Intelligence;

We used the same post-survey in the Architecting Forum¹ and the meeting with the industrial partners of our master program. In this way, we hoped to collect initial data to bootstrap the in-class assignment.

B. The in-class assignments

We guide the students in the class through a set of assignments following the course framework. However, these assignments² are more fine-grained than the framework. Figure 1 shows the first assignment to start shaping the line-of-reasoning. The format of these assignments is a balancing act in asking open questions to challenge the students, while being specific enough to get them going.

- Describe what problem triggers your research
- Be as specific as possible, for instance asking:
 - Why, what, how, who, when, where
- If you find it difficult to describe the problem, then start with listing symptoms and challenges, or identifying dilemmas

Fig. 1. The first assignment to start shaping the line-of-reasoning

We observe that this running case helps well to get the students going. Where we observed last year that we overstretched them with the same assignment (they did not really know how to start), we saw now that teams were actively discussing.

Shaping the line-of-reasoning and searching the literature worked out quite well. Rather than lecturing for half an hour about search strategies, they could start searching after a 10-minute introduction. During the literature assignment, most groups found review papers on the topic. Review papers form a welcome starting point for further literature exploration. Examples of the papers they found are:

- [7], rather limited and quite old review
- [8], not really a review, however, an interesting paper providing a competency framework
- [9], is a conference paper, not a journal publication in a rather specific domain. However, it is a true literature review, although it “only” has 30 references.

The third step in the framework, making the research design, was more challenging for this running case. We ran into an additional problem when we wanted the students to “play” with data to give them a feel for all data related aspects,

such as statistical analysis, bias, validity, et cetera. We did collect data beforehand for the Leadership case. However, the amount of data was too small for meaningful analysis. We had 44 responses from 3 different groups (8 + 10 + 26).

We decided during the execution of the course to add another case, where we wanted a case that would allow data gathering from a broader group of people. We used that case to have the students working on the data collection, e.g. formulating a survey, identifying potential people that may respond, and executing, the survey.

We landed on a question to research how many people follow the dentist recommendation to limit the consumption of food and drinks to at most 7 times per day (as stated on a poster in the dentist waiting room). Literature states, “*The frequency of consumption of foods containing free sugars should be limited to a maximum of 4 times per day*” [10]. We asked our students:

- Make a survey to find out if people are following the dentist recommendation.
- Add relevant questions to understand the survey respondents, e.g., age and gender

The first phase of this assignment worked excellent. The students experienced many pitfalls and dilemmas of setting up such survey. For instance, clarifying what the research really needs to know, how to formulate unambiguous, well-understandable questions, and selecting an appropriate scale and format.

The second phase was somewhat shocking for the teachers. Students barely remembered the most fundamental statistical quantities and formulas. They had clear difficulties to make sense from the collected data, beyond calculating an average. We had hoped that they would look at the distribution of the data (e.g. frequency of consuming food or drinks), the variation in the data, and the correlation between age or gender and the frequency. Our conclusion is that we need to give a refreshment assignment for statistics as preparation of the course.

IV. EVALUATION

At the end of the course, we asked the students to evaluate the course and the use of cases. The survey questions were Likert scale questions, with answers ranging from “fully disagree” to “fully agree”. We use a Net Promotor Score (NPS) [11] to assess the outcome. A score “fully agree” counts as attractor, “agree” is neutral for NPS, and the remaining scores are distractors. This is a quite strict assessment, based on the assumption that students expect to get something out of the case for every aspect, e.g. “agree” is “normal”.

¹ <http://www.architectingforum.org/index.shtml>

² All assignments are at <https://gaudisite.nl/SEcourseResearchMethodsAssignmentsSlides.pdf>

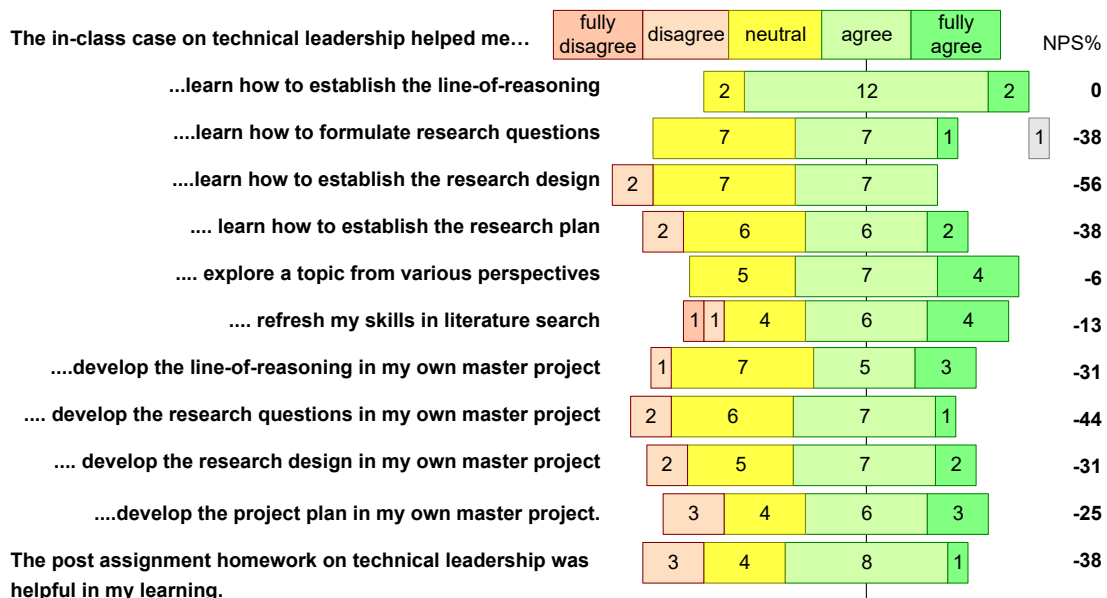


Fig. 2. Evaluation of the leadership case by the students, using NPS

A. Evaluation of the Leadership Case

Figure 2 shows the survey responses for the leadership case, based on 16 respondents out of 21 students. Centering the answers around “agree” visualizes the NPS. The figure shows the numerical value for the NPS expressed as percentage at the right hand side.

We can clearly see that the students are not satisfied yet with their learning and development from the leadership case. This is a rather strict interpretation, since the assumption that students will learn all these aspects in such short time may not be realistic. However, setting the target that high helps to see where to look for further improvements.

Looking at the NPS scores, we see that only *establishing the line-of-reasoning*, *exploring a topic from various*

perspectives, and *refreshing the literature search* work more or less as desired. The other aspects need improvement. Using a separate case for the data part did disrupt the research design.

B. Evaluation of the ad hoc Dental Case

Figure 3 shows the responses to the questions related to the second case, the dental case. The students score the *learning to formulate survey questions* negatively. That was somewhat of a surprise, since we observed during the assignment that students experienced much. In retrospect, students mostly experienced many pitfalls, e.g. what not to do. We did not teach them how to formulate effective surveys. This may be beyond the objectives of this course. However, then we should at least provide students with a pointer to sources explaining how to create good surveys.

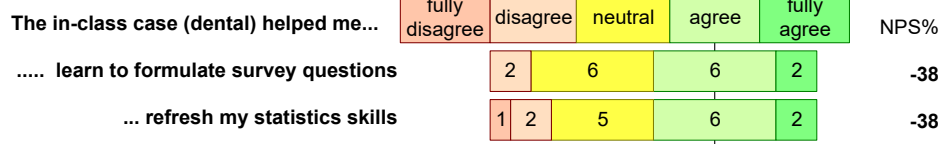


Fig. 3. Evaluation of the dental case by the students, using NPS

The students score the *refreshing of their statistics skills* negatively. Here we see a similar aspect as with formulating survey questions; refreshing statistics skills is an objective of this course. A course prerequisite is that students have basic statistics skills. The course objectives are to help students in developing their competence when and how to use these basic statistics skills for their research design and execution. This assignment mostly served now in detecting a lack of active statistics skills and the ability to look at data to make sense out of it.

C. Evaluation of the Learning Outcomes

Figure 4 shows the responses to the learning outcomes evaluation. These responses show appreciation for *defining the line-of-reasoning* and *planning my master project*. *Reviewing literature* and *designing the project research* score slightly negative in NPS. They are more reluctant in the learning outcomes that they need to fulfil in the upcoming execution phase, e.g. *writing academic texts*, *executing the research*, and *writing the final master project paper*. Since they have to learn these last 3 aspects during the research project execution, this lower score is not a great worry.

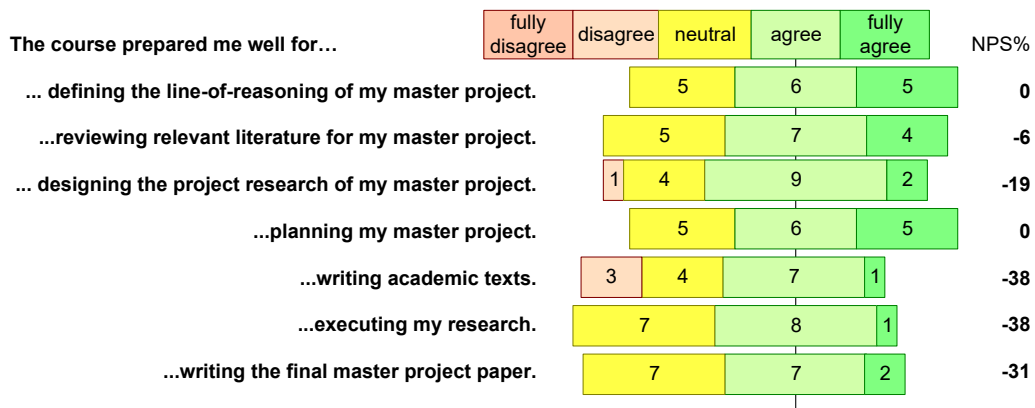


Fig. 4. Evaluation of the learning outcomes of the course

Students had the option to add textual feedback on a number of questions. A few suggestions about what may be removed from the course are relevant. One student writes, “I think a lot of what we learn here are thing one should know at this point, always good with a review, but I feel like lot of what we do here is unnecessary”. This probably depends on the preceding education. Our experience from supervising master projects shows a significant variation in the student population. Most students needed significant supervision in the line-of-reasoning, literature review, and research design. That contradicts this student’s statement. However, a critical question is whether the course is effective, which we keep on studying.

Another student remarks “Technical leadership case and dental survey. I would rather spend the time developing content directly related to my master project and get feedback on that.” That statement directly contradicts our move introducing an in-class case. Question is how well these students can make this statement, while not having experienced the course without cases. The need of this student, spending time and focusing on the own master project, however, is recognizable.

The question what we need to improve provides some more insights. A few students comment on the need to work on the homework and preparing the master project throughout the entire course. Apparently, we have to say that even more often than we have done. This remark is a symptom of a systemic problem in our course model, where we see that students tend to do their homework just-in-time (or just-too-late if it is more challenging than expected).

D. Evaluation of the Hybrid Course Format

Figure 5 shows the number of students that followed the course in the classroom and online. Sixteen of these students answered the survey at the end of the course, on the last course day. We included a set of questions to learn from the situation that Corona forced upon us.

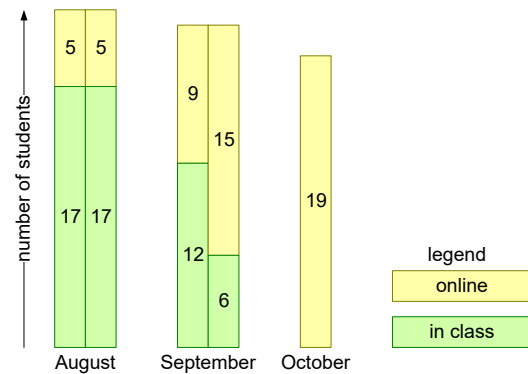


Fig. 5. Number of students in class and online

Figure 6 shows the outcome of the format related questions. The immediate conclusion is that teaching online worked better than we expected, and the students reasonably well appreciated the online format. As expected, students indicate that lecturing was easy to follow. They even indicate that keeping attention worked well (where the fact that they say that they pay attention does not implicate that they actually did so).

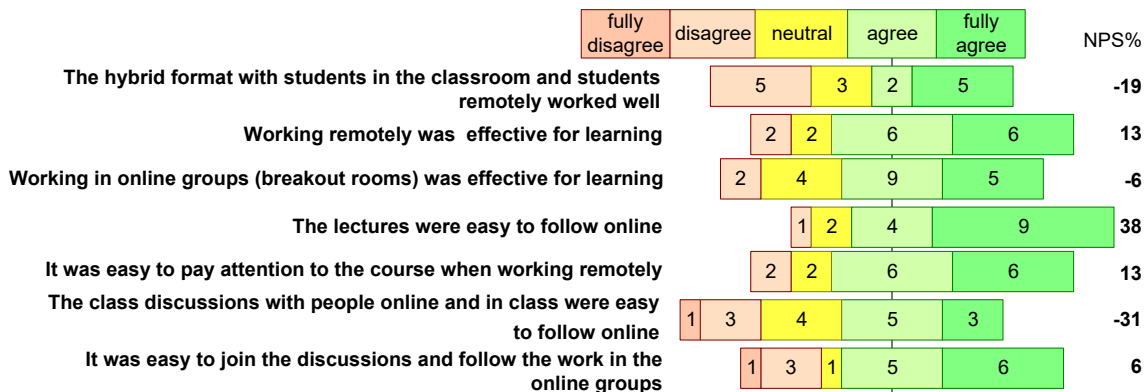


Fig. 6. Evaluation of the hybrid (in-class and online) format

Working in online groups scores positive too. The majority finds working remotely effective for learning. The

hybrid forms of teaching score the lowest, e.g. discussions with people remote and in class. This matches the teachers’

experience during the course. It is quite challenging to pay attention to people in the classroom and at the same time the remote people.

Most striking aspect of this evaluation is the large variation in answers. There is a significant number of students that consider online teaching effective, while a smaller group doesn't appreciate the online format.

The final question on "*I recommend continuing to offer this course as a hybrid (online and in-class) in the future*" received 9 positive and 7 negative answers. Some of the students would prefer online teaching outside of the Corona situation, mostly since it saves them traveling time. Others feel that the teachers treated online students too tolerant. We had several complaints about students that contributed too little in the group sessions online.

E. Grades of the Course Homework

Table 2 shows the grades that the students achieved for their homework. The number of poor scores (D and E) increased from 1 to 4, while percentage wise the high scores (A and B) were similar. The variation in the elements contributing to the grade (line-of-reasoning, literature, research design, writing, and overall coherence) was small. However, more than half of the students scored low on research design.

Grade	2019	2020
A	5	6
B	4	5
C	2	4
D	1	3
E	0	1

Table 2: Grade of students for their homework in 2019 and 2020.

F. Lessons Learned

A lesson we learned from this evaluation is that we need to find a case that allows us to collect a large amount of data in a short time. Letting the students formulate and acquire the data has clear value. However, we may have to use a pre-assignment to prepare the students and the case, so that the students are able to collect sufficient data during the course.

We cannot rely on prerequisite knowledge and skills such as statistics. That means that we need a pre-assignment to force students to refresh such topic.

The Corona situation forced us, as the rest of the world, on a steep learning curve for online teaching in a course with much interaction. We learned many practical aspects that go beyond the scope of this paper.

V. CONCLUSIONS

Researching SoS methods requires a wide variety of research methods. Teaching these methods to students requires context during the teaching. During the first year, students only used their future project as context. As consequence, they had a tough learning journey. In the second edition of this course, we added a running case for the students to work on. We observe in our interaction in the class that students easily connect to this running case, which helps them to learn the steps of the research approach.

However, the feedback from the evaluation by the students clearly shows that we need to evolve the case. In addition, the way the course is using the case needs further improvements.

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