On-line Meetings for Educating the Minds of Future Safety Engineers during the COVID Pandemic: An Experience Report

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Abstract: World-wide opportunities for "meetings of minds" was the goal of the research of visionaries who contributed to the creation of networked communication systems. During 2020, as a result of the COVID-19 pandemic, educational institutes massively exploited these systems enabling virtual spaces of synchronous and asynchronous meetings among students and among students and teachers. Technology alone, however, is not sufficient. Technological Pedagogical And Content Knowledge (TPACK) and competence are paramount. In this paper, I report about my experience in pedagogically designing and implementing an on-line version of an advanced master course on safety-critical systems engineering, conceived and delivered as a series of Zoom-based, and Community-Of-Inquiry (COI)-oriented meetings plus Canvas-based threads of discussions for educating the minds of future safety and software engineers. I also report about the limited but still talkative COI-specific questionnaire-based evaluation, conducted with the purpose of better understanding the limits of moving the course on line and elicit areas of improvement, given that likely education on-line is now here to stay. Finally, I elaborate on a roadmap for future development, based on the results from the first instance.

1 INTRODUCTION

Networked communication systems were conceived by visionary researchers whose purpose was to create world-wide opportunities for "meetings of minds". During 2020, as a reaction to the COVID-19 pandemic and the consequent urgent imperative to move online and contribute to social distance, educational institutes massively exploited these systems enabling virtual spaces of synchronous and asynchronous dialogues among students and among students and teachers. As known, however, technology alone is not sufficient. Knowledgeable and skilled personnel are needed. At Mälardalen University, Sweden, different initiatives have been introduced to support teachers lacking experience with on-line education to navigate in these challenging times. These initiatives aim at enabling teachers to achieve skills spanning from basic digital literacy, achievable via for instance few-hour courses on digital learning platforms and digital video-conferencing systems to pedagogical digital competence, achievable via formal university courses such as PEA929-Pedagogical digital competence (MDH-Mälardalen University, 2020e). With the purpose of creating opportunities for "meetings of minds" and acquiring the knowledge and skills necessary for addressing the challenges posed by online education, I took PEA929 while re-designing for on-line delivery DVA437 Safety critical systems engineering (MDH-Mälardalen University, 2020a), an advanced master course. PEA929 allowed me to achieve the necessary pedagogical digital competence, which then combined with my knowledge of content, as well as understanding of the complex interaction between the different types of knowledge components allowed me to re-design DVA437 for online delivery. In this paper, I report about my experience in pedagogically designing and implementing the on-line version of DVA437, conceived and delivered as a series of Zoom-based, and Community-Of-Inquiry (COI)-oriented meetings plus Canvas-based threads of discussions for educating the minds of future safety engineers. I also report about the limited but still talkative COI-specific questionnaire-based evaluation, conducted with the purpose of better understanding the limits of moving the course on line and elicit areas of improvement, given that likely education on-line is now here to stay and not just a tem-

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porary patch introduced to contribute to facing the COVID-19 pandemic. Finally, I elaborate a roadmap for future development based on the results from the first instance. The rest of the paper is organised as follows. In Section 2, I recall essential background information. In Section 3, I explain the pedagogical goal. In Section 4, coherently with the pedagogical goal, I present the COI-oriented redesign and implementation of DVA437. In Section 5, I present the results. Finally, in Section 6, I draw my conclusions and elaborate on a roadmap for future development.

2 BACKGROUND

In this section, I recall essential information about the Technological Pedagogical Content Knowledge (TPACK) framework, and current models and learning perspectives for an effective pedagogically digital learning experience. I also recall essential information on the advanced master course on safety-critical systems engineering, code DVA437, which I re-designed for on-line delivery.

2.1 TPAC Knowledge and Competence

Technological Pedagogical Content Knowledge (TPACK) is a theoretical framework for understanding teacher knowledge required for effective technology integration. TPACK introduces the relationships between all three basic components of knowledge (technology, pedagogy, and content) (Mishra and Koehler, 2006). At the intersection of these three knowledge types is an intuitive understanding of their complex interplay. Teachers are expected to teach content using appropriate pedagogical methods and technologies. Beside the knowledge, competence, which "is a performance-related term describing a preparedness to take action" (M. Søby, 2013), is also fundamental. Specifically, in the context of this paper, pedagogical digital competence is the competence in focus. This competence is defined as the "teacher's proficiency in using Information Communication Technology (ICT) in a professional context with good pedagogic-didactic judgment and his or her awareness of its implications for learning strategies and the digital Bildung of pupils and students" (Krumsvik, 2011).

2.2 Community of Inquiry Model

The Community Of Inquiry (COI) model (Garrison et al., 1999) is constituted of three core elements essential to an educational transaction: cognitive pres-

ence, social presence, and teaching presence. The COI model, illustrated in Figure 1, taken from (Garrison et al., 1999), assumes that learning occurs within the community through the interaction of the three core elements. Indicators (key words/phrases) for each of the three elements emerged via the analysis of computer-conferencing transcripts. These indicators permit the effectiveness of the implementation of the COI-model to be assessed. To make the paper self-contained, the definitions of these types of presence and the corresponding types of indicators are recalled in what follows.
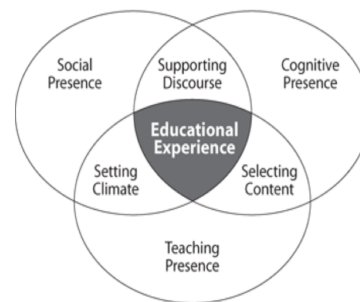

Figure 1: Community of Inquiry Model.

The *cognitive presence* is defined as extent to which learners are able to construct and confirm meaning through sustained reflection and discourse. Indicators related to this type of presence are: sense of puzzlement, information exchange, connecting ideas, apply new ideas.

The *social presence* is defined as the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop inter-personal relationships by way of projecting their individual personalities. Indicators related to this type of presence are: emoticons, risk-free expressions, encouraging collaboration.

The *teaching presence* is defined as facilitation, and direction of cognitive and social processes for the purpose of realising personally meaningful and educationally worthwhile learning outcomes. Indicators related to this type of presence are: defining and initiating discussion topics, sharing personal meaning, focusing discussion. The interested reader may refer to (Castellanos-Reyes, 2020) for a brief summary regarding the 20 years of progress in COI.

2.3 Learning perspectives

In this subsection, I recall three perspectives on learning: the objectivistic, the constructivist and social constructivist. According to the objectivist perspective on learning, According to the objectivist perspec-

tive on learning, learners are instructed by teachers. Teachers are expected to transmit knowledge to the learners. The main assumption is that knowledge is objective, a single objective reality exists. This perspective is recognised to be appropriate for subject matters based on factual technical or procedural knowledge. However, it is pointed out that the learning experience might be impoverished when students only act as passive recipients of content. According to the constructivist perspective on learning, "learning happens when learners construct meaning by interpreting information in the context of their own experiences. In other words, learners construct their own understandings of the world by reflecting on their experiences" (Gogus, 2012). According to the social constructivist perspective, the construction of knowledge is shaped by the social and cultural context. The learners come to construct and apply knowledge in socially mediated contexts.

2.4 DVA437

DVA437-Safety critical systems engineering is a 7.5 ECTS advanced course which is part of various Master's programmes (MDH-Mälardalen University, 2020c; MDH-Mälardalen University, 2020d; MDH-Mälardalen University, 2020b) at Mälardalen University. DVA437 was introduced for the first time in the fall semester of 2011 as 10-week course at a pace of 50%, i.e., a total student effort of around 20 hours per week. Until 2019 (before the spreading of the corona virus), it was delivered on campus via regular interactive theoretical lectures and guest lectures, typically given by industrial partners. The Intended Learning Outcomes of the course are:

1. Apply fundamental methods for hazard analysis. This ILO implicitly requires that students reach a mastery in dependability terms and concepts.

2. Apply safety standards for development of safety-critical systems. This ILO implicitly requires that students reach an understanding of the typical safety life-cycles and are able to describe specific portions of them in specific domains.

3. Create a safety case. This ILO implicitly requires that students reach a mastery in argumentation, evidence identification and classification.

4. Compare and contrast his/her work with respect to state of the art concerning safety case structuring.

These ILOs were formulated according to the SOLO (Structure of the Observed Learning Outcome) taxonomy and the course has been designed according to constructive alignment principles (Biggs and Tang, 2007), combined with the education-oriented

ISO 26262 interpretation (Gallina, 2015), where ISO 26262 (ISO/TC 22/SC 32, 2018) is a standard for functional safety in the automotive domain. The course is advanced and as such it expects students to reach in-depth knowledge and skills. The third ILO "create a safety case" , for instance, explicitly states the expectation for the so called "extended abstract" level of understanding. Students are examined via a written exam as well as project work which includes an oral presentation, during which students are not only expected to present orally their work but also act as opponents/discussants while class-mates present. The project work always proposes real life challenges provided in cooperation with industrial partners.

3 PEDAGOGICAL GOAL

In this section, the pedagogical goal for the on-line version of DVA437 is set. Specifically, based on the theories presented in Section 2, intersecting the intersections (Figure 2) is set as the main pedagogical goal. This translates into first striving for:

- a synergetic perspective on learning where all perspectives are considered of value and complement each other. This means that partly the knowledge is transferred from the teacher to the learners (especially factual knowledge such as the terminological framework related to dependability), partly is constructed individually (via individual project-related assignments) and partly is constructed cooperatively (via group-based assignments) via a social discourse;

- an educational experience where all types of presence are present;

and then striving for intersecting the intersections by offering an educational experience where all types of presence are present and a synergetic perspective on learning is in place.
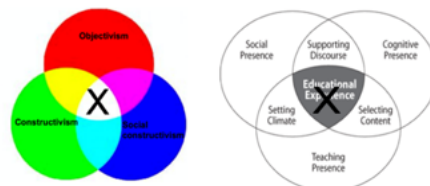

Figure 2: Perspective and presence intersection.

4 COI-ORIENTED DVA437

In this section, I describe how globally the DVA437 course (Section 4.1) and how each single lecture (Section 4.2) was redesigned and then implemented to comply with the COI model. It shall be noted that partly the redesign was inspired by (Fiock, 2020).

4.1 Course redesign & implementation

As mentioned in Section 2, DVA437 was designed with constructive alignment principles in mind. That design was preserved and made explicit for students by drawing the corresponding mindmap, which not only shows the alignment but also emphasises the teacher and the student role with respect to the teaching & cognitive presence. The mindmap, which was included in the DVA437 study-guide, is given in the Appendix. Regarding social presence, to motivate students and create a community-feeling, I have provided examples of job-advertisement regarding positions for safety engineers where it was clearly stated that the required skills were the same as the ones formulated by the first 3 ILOs. In addition, I have sent a welcome message. I have prepared a rather detailed study-guide, where I included a Zoom-related "etiquette", which among other aspects was recommending students to add their photo, turn on their embedded camera, use the chat to interact constructively with the teacher and the other students.

4.2 Lecture redesign & implementation

At lecture-level, each lecture was redesigned to explicitly structure the different types of presence and learning perspectives. The initial and final part of the lectures are explicitly dedicated to the social constructivist perspective and cognitive presence. The core of the lecture is explicitly dedicated to the objectivistic perspective and teaching presence. During which however students are stimulated with questions and 1-3-minute exercises to allow them to act not only as content recipients but also content processors. Figure 3 provides an example of a typical outline of DVA437 lectures.

Each Zoom-based lecture was started in good time (30 minutes earlier) to allow students to gather and eventually interact as well as formulate their doubts. Thus, each lecture was explicitly preceded by part dedicated to the social presence. At the end of each lecture students were challenged with exercises and in various cases explicit discussion threads on Canvas were opened to allow them to individually construct knowledge.

Outline

- My understanding so far…
- Today- Questions –Inquiry-based learning
- New Content–Direct instruction
  - Safety case
    - Safety management
    - Risk Acceptance Principles (RAPs)
    - Logic and epistemic doubts
    - Essential elements
  - Safety case documenting/modelling (Breadth first intro)
- Summary/Discussion

Figure 3: Typical outline of DVA437 lectures.

5 RESULTS

In this section, I report about the quantitative results based on the first experience.

From a COI perspective, the teaching and cognitive presence were present during the verbal interaction. A subset of students was definitively active asking questions during the theoretical as well as the practical lectures and guest lectures, participating to the role-play constructively. The social presence instead did not have specific contexts to be able to develop itself. Concerning the assessment of the COI model from a chat-perspective, I counted the typical COI indicators by inspecting manually the chats, which were automatically saved by Zoom. Regarding indicators of social presence, only one emoticon from my side was included in the chat, no significant risk-free expressions, and regarding encouraging collaboration some indicators were present but mainly included in my own messages sent to either individual students or to all attendees. Regarding cognitive presence, I noticed that the number of indicators gradually increased throughout the course-period. This clearly highlights that it takes time to set the climate for meaningful cognitive presence.

In addition to the analysis of the chats, given the novelty of the course-delivery and the desire of assessing at least partly the achievement of the pedagogical goal, which was clearly set, as well as better understanding the advantages and limits of moving the course on line, I have sent to students a COI-focused questionnaire (Arbaugh et al., 2008), currently, downloadable from the COI-site (COI-Community of Inquiry, 2020). As reviewed by (Stenbom, 2018), this questionnaire has been used effectively to examine learning experiences and to compare different premises in many contexts. Thus, I sent it to 16 regular students who: 1) took the course this year, 2) attended the lectures, and 3) were active during the project work. Figure 4-6 show the histograms related to the three types of presence.
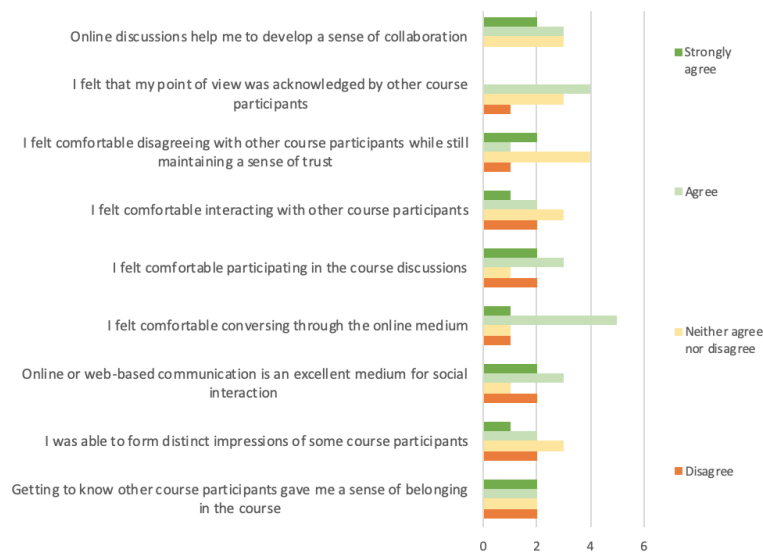
Figure 4: Social presence.

Figure 5: Cognitive presence.

In addition to these histograms, even if not shown in this paper, sub-scale scores were computed for each respondent for each of the three scales as a mean value of the numerically coded responses. For sake of clarity, it shall be stated that the questionnaire was not proposed as an anonymous questionnaire. The reason for this choice is twofold: 1) "students should be treated as adult partners and that an objective and open exchange regarding the performance quality must be possible"; 2) studies such as (Scherer et al., 2013) point out that "no significant differences are identified in the informative quality of data between the anonymous and personalised student evaluations".

From a quantitative and throughput-focused perspective, the throughput after the first examination in relation to the written exam, if compared with the previous instance, decreased negligibly (this year, 72,22% passed the written exam, while 73% passed the written exam last year). In relation to the project work, instead, the throughput increased (this year, 89% passed the project after the first examination, while only 82,75% passed the previous year). From these numeric results, it emerges that the throughput did not suffer by having moved the teaching on-line.

As mentioned, my threefold purpose with this questionnaire/results-analysis was to: assess the implementation of the Community of Inquiry Model, better understand the limits of moving the course on line, and elicit areas of improvement given that likely education on-line is now here to stay.
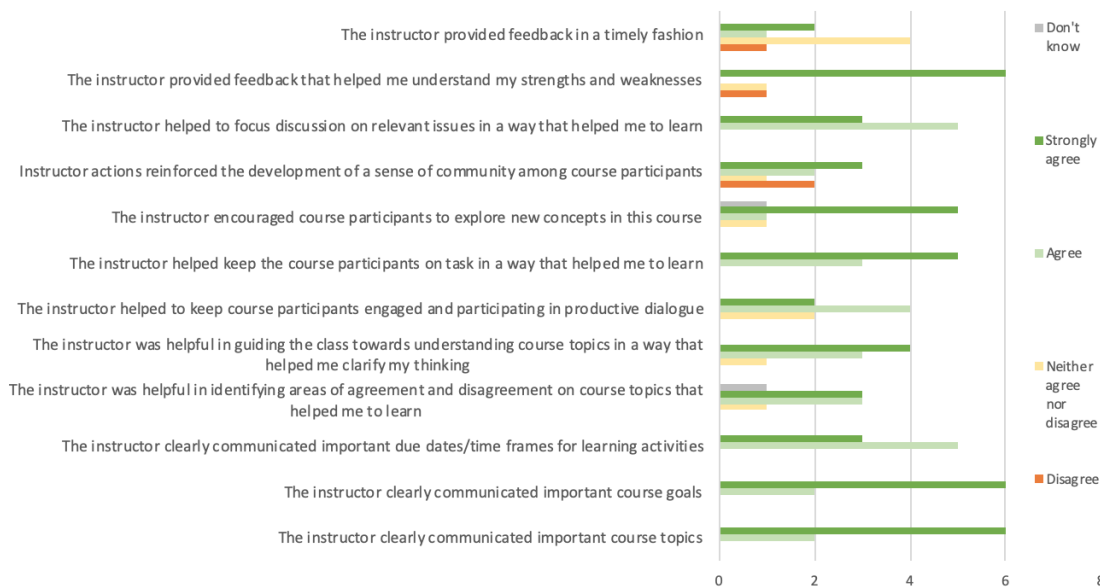
Figure 6: Teaching presence.

Based on the answers received (8 students provided their answers, i.e., 50%), the main lacking aspect resulted to be the social presence. From a teaching and cognitive presence, the respondents were globally satisfied. Concerning timely feedback, this year, it was an exceptional situation due to the short notice sick-leave of the course assistant. Given this limited but stil talkative results, it emerges the need of substantially enhancing the social presence. However, room for general improvement is present.

6 CONCLUSION AND ROADMAP

In this paper, I reported about my experience in pedagogically redesigning and implementing an online version of an advanced master course on safety-critical systems engineering, conceived and delivered as a series of Zoom-based, and community-of-inquiry-oriented meetings plus Canvas-based threads of discussions for educating the minds of future safety and software engineers. Based on the results from the first instance, a roadmap for near-future development can be sketched as follows. To improve the social presence, I plan to:

- introduce a Zoom-based lecture-zero, during which we could create a virtual round table and present ourselves;
- use break-out rooms before and after the lectures to create the virtual corridor facilitating small-talks.

- open Canvas-discussion-forum for enabling students to professionally present themselves in relation to a set of assumed skills, which are helpful for project work. This year a discussion forum was opened but not in a structured manner and as a consequence it was not exploited as expected.

To improve the cognitive presence as well as increase contexts for social constructivist learning, I plan to:

- use break-out rooms to enable students to work in small groups and solve the typical 2-3-minute exercises;
- use polls to assess the individual cognitive presence;

To improve the teaching presence, I plan to:

- make explicit for the students the usage of technology in relation to a specific learning perspective and type of presence. This should allow me to extend the COI-specific survey to get feedback from students with respect to the effectiveness of the usage of specific Zoom-or-Canvas features.
- introduce an exit-questionnaire for each lecture to understand if the questions/challenges asked/posed within the lecture can be answered/faced by the individual students.

As future development, inspired by (Zhu et al., 2019), I also plan to explore Computer-Mediated Discourse Analysis (CMDA) for analysing the participation in online discussion and students' learning behaviours in relation to CoI presences. A more formal evaluation is expected to be addressed, implemented,

and analysed based on data collected over a longer period, comprising multiple DVA437-course instances, possibly based on a larger sample of questionnaire responses.

ACKNOWLEDGEMENTS

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APPENDIX

DVA437

ILO-1-APPLY FUNDAMENTAL METHODS FOR HAZARD ANALYSIS

- Teaching-activities
  - Lectures-on-Dependability
    - Dependability-Attributes
    - Dependability-Threats
    - Dependability-Means (fault forecasting, etc.)
  - Project-Slot
  - Lectures-on-Hazards-Analysis-and-Risk-Assessment
    - HAZOP
    - FTA
    - FMEA
- Learning-activities
  - Study slides/course literature
  - Active learning -> synchronous/asynchronous participation
  - Relate/Apply/Create
- Assessment-activities
  - Project-Assignment
  - TEN/HEM

ILO-2-APPLY SAFETY STANDARDS FOR THE DEVELOPMENT OF SAFETY-CRITICAL SYSTEMS

- Teaching-activities
  - Lecture-on-Safety-critical-Systems-Intro
    - Languages (for modelling the architectural specification-focus on CHESSML)
  - Lecture-on-ADL
  - Lectures-on-Safety-Standards
    - ISO 26262-Part3-4
    - ISO/PAS 21448
    - DO-178C & related standards
    - EN 50128 & related standards
    - IEC 61508
  - Guest-Lecture-Rail-Sector
- Learning-activities
  - Study slides/course literature
  - Active learning -> synchronous/asynchronous participation
  - Relate/Apply/Create
- Assessment-activities
  - Project-Assignment
  - TEN/HEM

ILO-3-CREATE A SAFETY CASE

- Teaching-activities
  - Lectures-on-Safety-Cases
    - Methods/languages for documenting safety cases
  - Roleplay-on-argumentation
  - Project-Slot
- Learning-activities
  - Study slides/course literature
  - Active learning -> synchronous/asynchronous participation
  - Apply/Relate/Create
- Assessment-activities
  - Project-Assignment
  - TEN/HEM

ILO-4-COMPARE AND CONTRAST HIS/HER WORK WITH RESPECT TO STATE OF THE ART CONCERNING SAFETY CASE STRUCTURING

- Teaching-activities
  - Mini-Lecture-on-Related-Work
- Learning-activities
  - Study slides/course literature
  - Active learning -> synchronous/asynchronous participation
  - Apply/Relate/Create
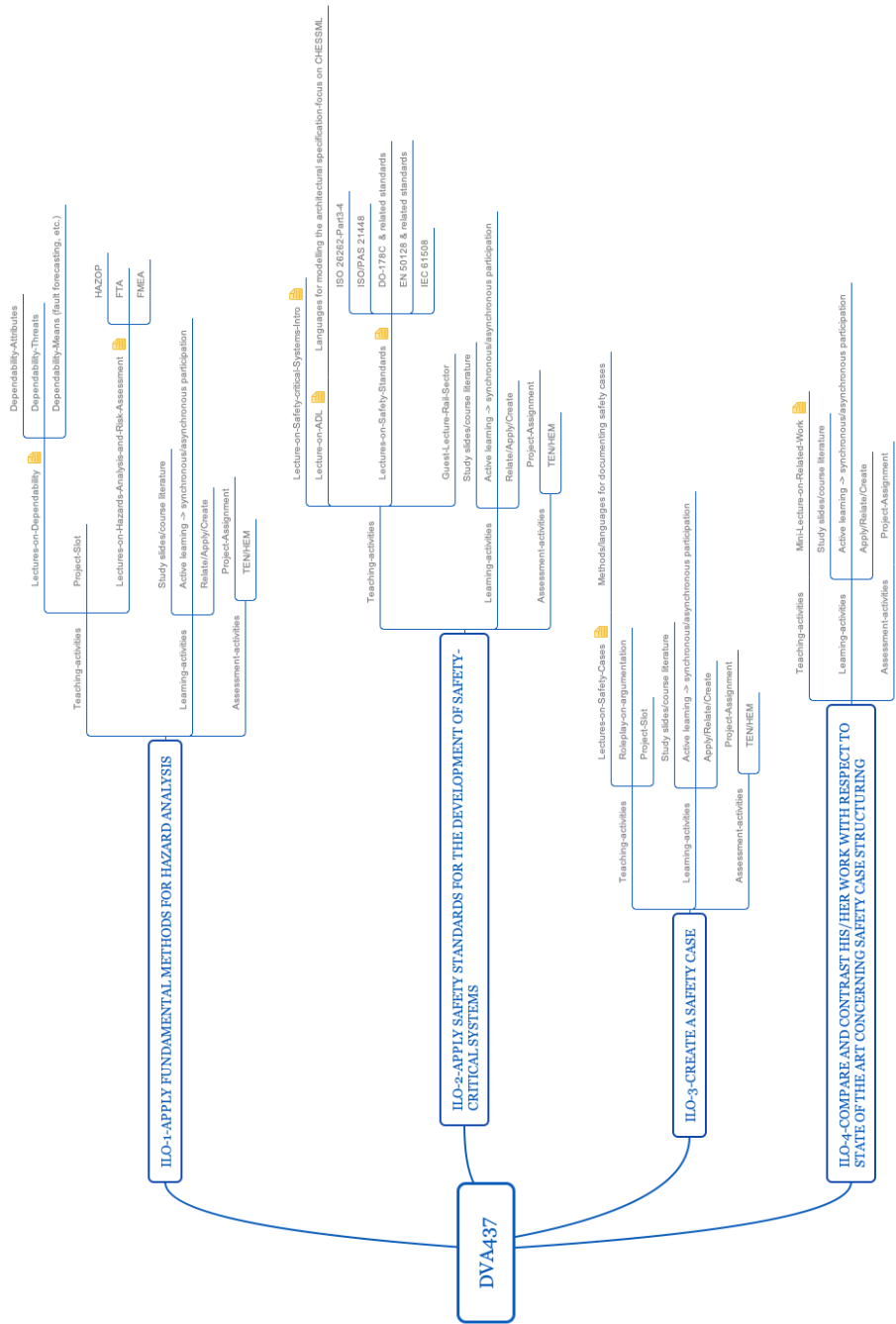- Assessment-activities
  - Project-Assignment

Figure 7: DVA437 Mindmap showing the alignment of ILOs, teaching/learning/examination tasks.