CResDET

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Erasmus+ Project Crisis-Resistant Digital Education and Training

Erasmus + Project: Crisis Resistant Digital Education and Training

Planning ahead for future crises!

Guidelines for engineering educators to design resilient online environments

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Disclaimer:

The impact of crisis scenarios on educational activities is broad and multi-faceted. Additional factors could be considered when revising a course for more crisis resilience. What was included in the description of the scenarios and the adaptation of courses in higher education is tailored to the digitization of content, presupposing that both the student and the higher education institution have the necessary digital infrastructure. A more extensive version of the framework will be provided to enhance usability. However, this guideline document pinpoints the main aspects that need to be addressed to adapt educational activities to crisis conditions and provides links to further reading materials on the project website: www.cresdet.eu.

1. INTRODUCTION

A crisis, no matter the magnitude, subjects teaching activities to a series of restrictive boundary conditions. University teaching staff that is already working in a field of tension between delivering high-quality education and conducting research activities additionally must react to those often rapidly changing conditions (Rapanta et al., 2020). The COVID-19 pandemic demonstrated that this demand for flexibility has been met by switching to a virtual learning environment, later termed emergency remote teaching that considers the deficits compared to well-planned online courses (Hodges et al., 2020, Bao, 2020). Deficiencies arose from educators having to improvise solutions often lacking time, experience and support personnel to properly deliver the transition towards a suitable crisis-resistant counterpart.

Digitalization plays a crucial role in crisis-resistant teaching due to its ability to facilitate the continued delivery of education, foster connectivity, and enable exchange among students and educators, regardless of physical limitations or disruptive events. By leveraging digital tools and platforms, educational institutions can overcome various challenges and ensure uninterrupted learning experiences. During times of crisis, such as natural disasters, pandemics, or unforeseen disruptions, traditional face-to-face teaching methods may become impractical or impossible. However, with digitalization, educators can swiftly transition to online platforms, ensuring that learning can continue without major interruptions. A digitalized learning environment also offers a multimodal infrastructure for content delivery. Various media formats can be utilized, including reading materials, audiovisual lecture recordings, curated materials from external sources such as YouTube or educational podcasts, and relevant news articles. This diversity of media enriches the learning experience, catering to different learning styles and preferences. Students can engage with content in ways that resonate with them, promoting deeper understanding and knowledge retention.

On this basis, it can be acknowledged that there is a demand for forward planning and preparation of remote teaching activities, revealing the actual adaptability in delivering quality education during a crisis event and creating awareness in educators about their readiness to employ ICT tools.

2. GUIDELINES FOR ENGINEERING EDUCATORS TO DESIGN RESILIENT ONLINE ENVIRONMENTS

In the scope of the CResDET project, a framework for crisis-resistant product development courses (Schramek et al., 2022) has been developed. Its contents and resources aim at adapting teaching activities to rapidly changing boundary conditions in the event of a crisis. They can be grouped into three domains (see Figure 1):

The Crisis Domain consists of steps to identify and characterise crisis-related restrictions and decide on the necessary level of digitalisation for the given scenario.

The Content Domain groups steps to revise educational goals and teaching activities taking into account previously defined crisis conditions.

The Validation Domain composes of processes to validate the adapted course layout and ensure that students can achieve intended learning outcomes.

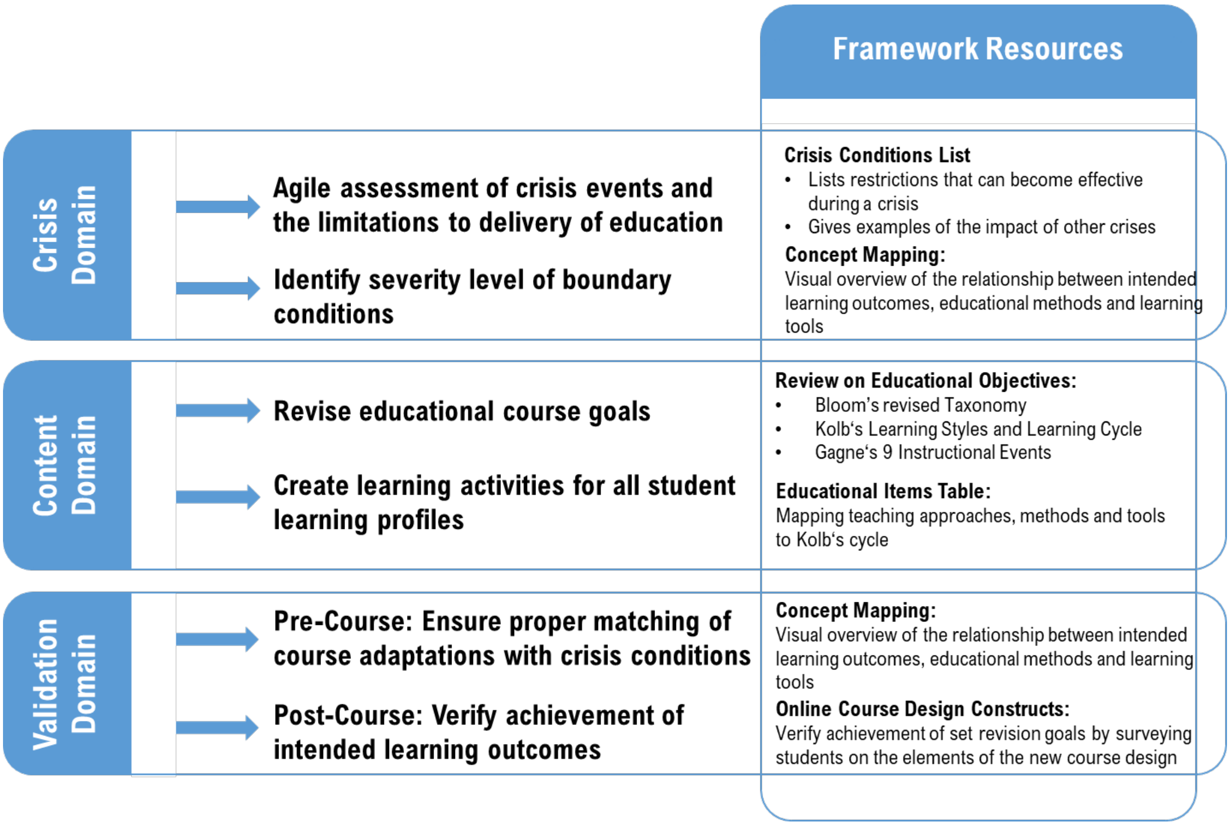

Figure 1: Overview of the framework for crisis-resistant product development courses

Based on the learnings from implementing the framework, practice-oriented guidelines for the digitalization and adaptation of educational activities in the event of a crisis were established. They aim at guiding educators through the framework step by step and demonstrate how to apply the proposed methodology for their courses by giving practice examples.

2.1. CRISIS ASSESSMENT

Assessing course resilience by conducting crisis scenario planning helps educators to evaluate whether educational objectives can still be met in the event of a crisis. For example: How can teaching activities be upheld in the case of the lecturer becoming unavailable?

Characterizing a crisis event by specific crisis limitations is crucial in highlighting deficiencies in the delivery of education and identifying potential challenges for both educators and learners. By understanding the unique constraints imposed by a crisis, educational institutions can better prepare and adapt their teaching methodologies to ensure effective learning outcomes. The framework provides a list of generic crisis conditions synthesized from past, present and potentially future crises, that can assist in creating a holistic description of a current crisis scenario. Depending on the severity of restricting crisis conditions (e.g. lockdown, travel ban), an educator is supported in choosing among physical, hybrid or completely online teaching modes.

Table 1: Crisis characterization for the condition Freedom of Movement (excerpt from the Output IO3_ Applying the CResDET Methodology to enhance the European Product Development Course in Pro Hackin')

Category	Subcategory	Condition/description, impact and explanation
Freedom of Movement	**Not applicable**	**Condition:** "Restriction of international movement" **Impacts and consequences:** Educational activities that require international movement are only possible with restrictions. If these restrictions cannot be met in an appropriate manner, education needs to take place on a national or digital level. **Explanation:** This digital course enables the international mobility of students for a few days (4 to 6) in a semester. The remaining part of the semester the students are typically set at their own institutions for regular classes, each of them with potentially different timetables.

2.2. ASSESSING IMPLICATIONS ON EDUCATIONAL OBJECTIVES

Existing course modules in higher education consist of and are limited by accredited procedures, therefore all digital transformations need to be evaluated against the accreditation document (Vukašinović et al., 2022). Module descriptions formulate intended learning outcomes (ILOs), that outline the knowledge or skills a student will acquire by following the listed teaching and learning methods and contain adequate assessment instruments to measure and verify the achievement of ILOs.

Once the set of restricting boundary conditions has been established, ILOs, tools and methods need to be checked for their continued suitability and revised appropriately. Educators may therefore analyze the impact of each crisis condition on the implementation of teaching activities stated in the course module description.

Utilizing concept mapping to visualize crisis impacts

Concept mapping can be a useful tool to visualize the relationships between ILOs, educational methods and tools supporting the delivery of education. Considering rapidly changing crisis conditions the method can allow for an agile assessment of the limitations imposed on the delivery of education at any time before, during and after a crisis event. Educators can thereby identify tools and learning activities that are no longer feasible or require modification and get a big picture of whether ILOs can still be achieved under the given crisis conditions. The concept model can be visualized as a layered onion model having the course's intended learning outcomes in the core. Intended learning outcomes are stated in the module description and define the knowledge and skills a learner will acquire upon completing the course, therefore providing a starting point for the conceptualization. ILOs are achieved by conducting learning activities, whereas boxes describing ILOs (see Figure 2) contain the respective activity that is planned to enable students the appropriation of said knowledge. The second layer contains learning activities based on educational methods and approaches. Each method might require specific tools to be executed, therefore the descriptions of methods are linked with the respective tools. The outermost layer contains tools that are necessary to conduct the course.

As a practical example, the course layout for Virtual Product Development held at the Technical University of Vienna will be visualized in its pre-pandemic state. Figure 2 depicts the layout of the Virtual Product Development course held at the Technical University of Vienna before the Covid-19 pandemic. The course formulates several ILOs to teach students the fundamentals of methodical development and design of technical systems and products, as well as introducing IT-based CAx applications to validate designs early on.

The intended learning outcomes formulated in the course description are the following:

- Contribute to product development activities methodically and understand the functioning of corresponding IT systems
- Assess the value of early involvement of IT-based methodologies in product development
- Explain VDI-based models
- Explain various CAx procedures, specifically to discuss the process of FE methods
- Include other domains of product development such as electrical engineering or computer science (cross-sectional competence)

Learning activities enable students to engage with the course contents and educators to adopt the intended learning outcomes. The course features the following educational approaches and methods:

- Ex-Cathedra Lectures
- Project-based learning including an industrial partner that provides a task and requirements
- Tutor counselling during the embodiment of the product
- Formative verbal assessment by tutors during weekly meetings
- An oral examination of the project outcomes

- A multiple-choice examination to assess the knowledge covered in the lectures

Students receive ex-cathedra lectures on the course topics and carry out project-based exercises to apply their knowledge. The exercise is conducted with industrial partners and student teams (Racing Team and Space Team) that provide a task assignment for the students to develop solution concepts and a virtual prototype. During the course, student teams receive guidance from academic tutors checking their progression and understanding of the assignment. The course is concluded by a final exam consisting of multiple-choice and open-ended types of questions, as well as a final presentation in which students have to explain their rationale and the procedure of the assignment. Student-educator interactions take place on campus however, questions can be posed in a forum section of the learning management system, as well as via email.

The learning tools that are required to conduct all activities are the following:

- Computer Aided Design Software
- Finite Element Analysis Software
- Topology Optimization Software (optional for motivated students)
- Learning Management System
- Presentation and Word Processing Software

The tool CAD software for example is necessary during the embodiment design phase of the project, therefore linked to the project-based learning approach. The project-based learning approach is again necessary for students to learn how to contribute to product development activities methodically and understand the functioning of corresponding IT systems. Later in the document, the adapted course layout for the Covid-19 pandemic will be used to demonstrate how to validate the proper fitting of adjustments to crisis conditions.

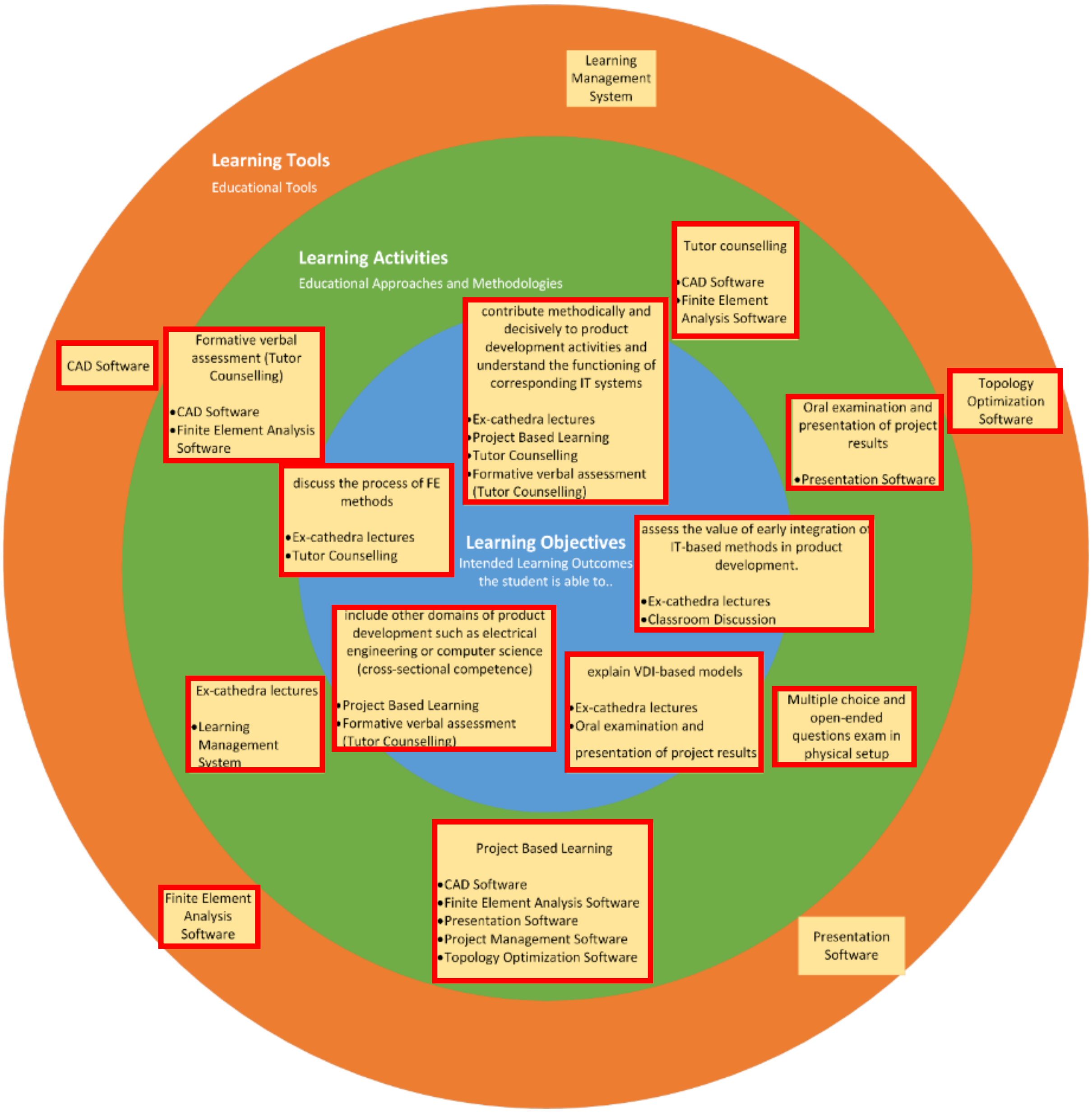

Figure 2: Concept mapping of pre-course layout

The impact of Covid19 on the accessibility, availability and feasibility of learning tools, activities and objectives is indicated by the red squares in Figure 2. It can be seen that none of the intended learning outcomes can be supported and delivered as planned, which can be explained by the loss of physical interactions in the classroom and computational resources and software licenses of the CAD Lab. Therefore substantial changes to the course layout needed to be considered.

How to revise educational goals?

Bloom's revised Taxonomy (Bloom et al., 1956, Anderson et al., 2001, Armstrong, 2010) defines different learning objectives, thereby setting a target reference for adapting strategies, tasks and instructions for an online learning environment. Whether educators plan on revising an existing module or creating a new one, Bloom's taxonomy can help them in categorizing their educational objectives into six major categories, with higher levels building on more basic ones: a learner must remember (lvl-1) basic concepts in order to understand (lvl-2) them and organize them into a coherent framework. This makes it possible to apply (lvl-3) that knowledge to execute tasks in new situations. This enables the possibility to analyse (lvl-4) what was done and then evaluate (lvl-5) it, as the critical judgement of the outcomes is the key to create (lvl-6) new knowledge. This distinction can help educators to define objectives for knowledge, skills and abilities and to design sequential (e-)learning activities that build on and complement each other accordingly.

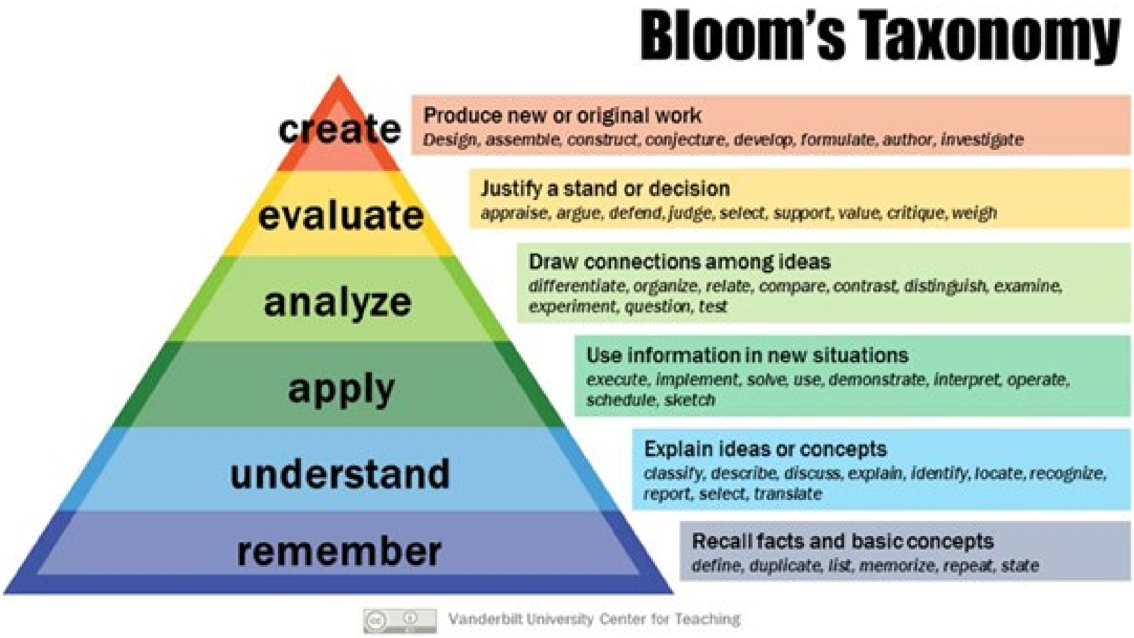

Figure 3: Bloom's Taxonomy
Source: Armstrong, P., Vanderbilt University, https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

How to create engaging learning activities?

From the perspective of a student-centred approach, it is important to consider that not all students are the same. They have different cognitive abilities or, better, they are more familiar and find it easier to leverage some of their skills to acquire new knowledge and reuse it across the different abilities set by Bloom's taxonomy. Honey and Mumford (1986 & 1992) defined four categories of learners, which are characterized by behavioural characteristics that aim at distinguishing different styles of learning as well as the conditions that favour the acquisition of knowledge and the achievement of learning outcomes. The four different Student learning profiles (SLP) can be classified as follows: Whether they are Activists (they learn by doing); Reflectors (they elaborate on observations); Theorists (they abstract and create models to learn) or Pragmatists (they experiment), educational methods and tools the educator will implement should enable them the opportunity to learn in the easiest way possible and let them familiarize with different learning styles.

Kolb's Experimental Learning Cycle (Kolb, 2015) appears to be one of the pedagogical approaches that are well suited to answer this request for student-centred learning. For these reasons, the table containing a list of educational items (tools, methods and approaches) already maps them to the stages of Kolb's Cycle, suggesting how/where to use them in physical and/or remote settings and in which kind of educational activity (lecture, seminar, lab, etc.).

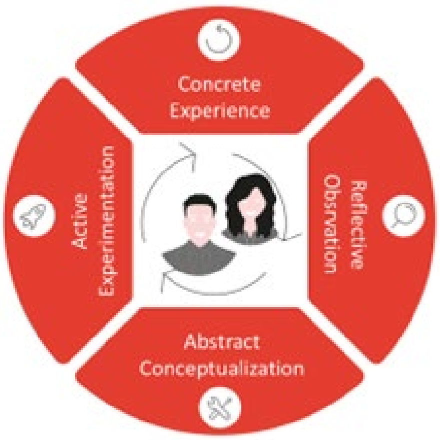

Figure 4: Kolb's Cycle

For the Virtual Product Development course, educational items can be allocated as in Figure 5.

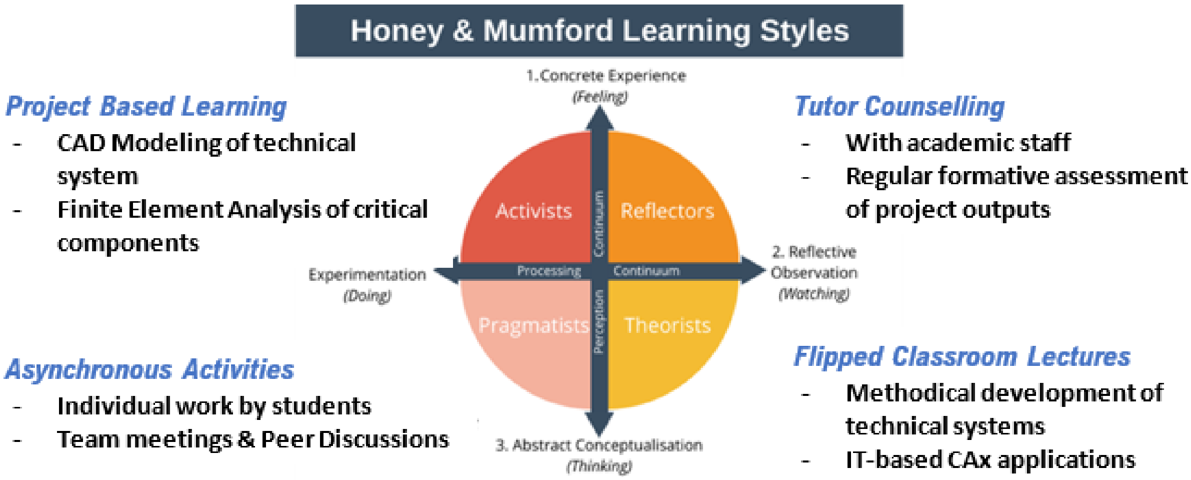

Figure 5: Educational items allocated with reference to learning styles

2.3. PRINCIPLES FOR THE PLANNING OF LEARNING ACTIVITIES

Learning activities are directly linked to a set of intended learning outcomes and are designed to allow students to engage with the course contents and receive feedback on their progress. Having established a student-centered approach to revisiting educational objectives, a teacher's perspective provides further insight into instructional design and sequencing of the course delivery.

How to create engaging and meaningful online learning activities?

Gagne et al. (1992) devised a set of instructional principles that in conjunction with Bloom's revised taxonomy and Honey and Mumford's learning styles can help in laying out an engaging and meaningful learning path for students (Singapore Management University – Centre for Teaching Excellence, 2023). Educators can use these principles as a checklist for their course elements.

Figure 6: Gagne's Nine Events of Instruction
Source: Lesson Planning, Singapore Management University, https://cte.smu.edu.sg/approach-teaching/integrated-design/lesson-planning

Gain Attention: Attract students' attention so they will pay attention as the educator presents the lesson material.

Inform Learner of Objectives: Communicate learning objectives to the students and give them time to arrange their thoughts about what they are about to see, hear, or do.

Prior Learning: Encourage the recall of prior knowledge.

Present Content: Use a variety of approaches to provide new material, such as lectures, readings, exercises, projects, multimedia, and others.

Provide guidance: Inform students of resources and learning practices that will help them understand the material and are less likely to waste time or become irritated by the use of incorrect facts or poorly understood concepts.

Practice: Let students use their newly acquired knowledge and abilities.

Provide feedback: To evaluate and promote learning, give pupils immediate feedback on their performance.

Evaluate performance: Check to see if the anticipated learning outcomes have been attained in order to assess the efficacy of the instructional events.

Enhance retention and transfer: Encourage students to apply knowledge to their personal contexts to improve information retention and transfer.

2.4. COURSE VALIDATION

Course validation can be carried out before, during and after the course is put into practice to ensure the proper fitting of adaptations with crisis conditions and to assess whether students are supported sufficiently in meeting intended learning outcomes.

Pre-course Validation - Utilizing concept mapping to validate the revised course layout

Pre-course measurements include reflection rounds with collegial educators and other course stakeholders supporting the delivery of educational activities. Concept mapping can in turn help all those involved to get a good idea of the revised course elements and develop an implementation plan. The conceptual map can potentially also be shared with students at the beginning of the course to enhance their understanding of how to achieve their learning outcomes and to establish a course overview.

Figure 7 depicts the visualization of the Virtual Product Development course layout after measurements against the Covid19 pandemic have been implemented. The regular ex-cathedra lectures were substituted by a flipped classroom type of lecture, where students are provided with recorded lectures and reading materials in advance of a distance session which they can use to discuss the contents with the lecturer. The lecturer established high levels of presence to facilitate active participation and classroom discussion during those classes. The summative assessment for the lectures was conducted via a multiple choice and open-ended type of questions test in the learning management platform.

For their project-based learning assignments, students were allowed to choose freely how they wanted to collaborate but were suggested online tools such as the platform MS Teams with office applications and cloud storage and online whiteboard tools such as Miro. Students were tasked to additionally prepare Gantt Charts to plan out the assignment throughout the semester and define quality gates with their tutors. Students that did not have the necessary computational resources to run the recommended computer-aided design and finite element analysis software (PTC Creo) were provided with remote desktop connections from the CAD Lab. During the course, tutors conducted their counselling online and checked on the progression of the assignment. By taking control of the shared screen during a videoconference, it was possible to assess CAD and FEM models and to give remote assistance with the software. Concluding the exercise, students presented their outcomes in a remote meeting, where the lecturer and tutors could again assess the virtual prototype by taking over the shared screen.

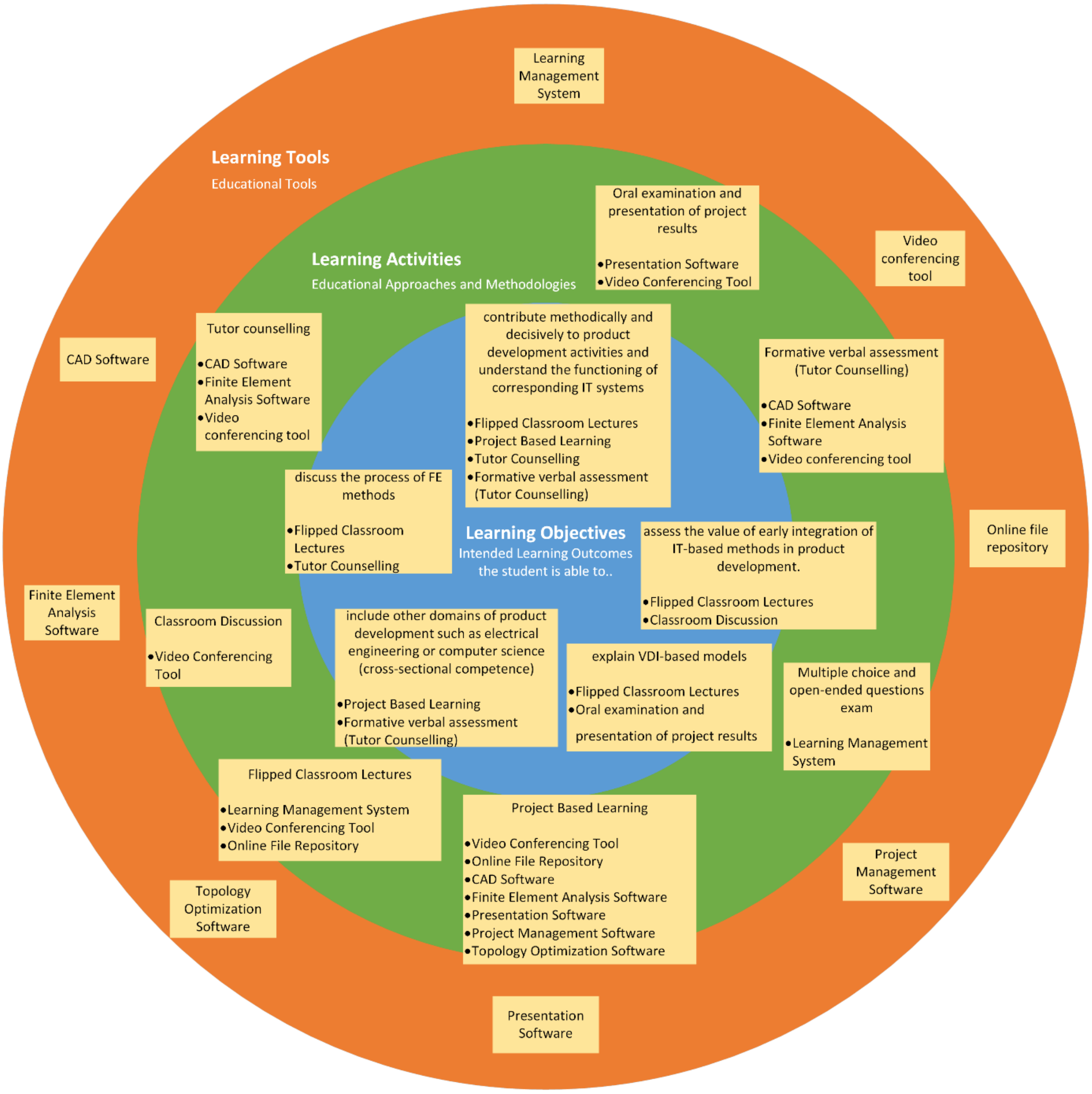

Figure 7: Concept mapping of the post-crisis course layout

Mid- and post-course evaluation

When testing the revised course layout in the crisis setting, the educator has to carefully monitor whether set learning outcomes are met and if student learning styles are addressed. Mid-course evaluation can happen during the course through direct observation of learning progress in live classes and during formative assessments. Surveys can be employed throughout and at the end of the course to assess student satisfaction, engagement, knowledge retention and to guide and improve the course content.

For a more in-depth description and examples of how the framework has been applied already please also check IO3_Case Study: Relocation of all Faculty Facilities at UniZag and IO3_Applying the CResDET Methodology to enhance the European Product Development Course in Pro Hackin'.

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