Specification:

Educational & Didactic Concept

Within the Erasmus+ Knowledge Alliance ProDiT – Projects for the Digital Transformation

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Summary

The Educational and Didactic Concepts are the basis for the delivery of the eLearning modules. The Open Communities of Practice (OpenCoP) develop the eLearning modules on the specified topics. The modules are composed out of a selection of educational resources and didactic formats. A module supports different learning trajectories (from competence and learning point of view) and student journeys (from organizational point of view), meaning, it can be tailored and adapted to different target groups (e.g. professionals, Master students), to different competence goals (e.g. by selecting content), to a different depth or direction (e.g. by adjusting the amount of content or workload hours) and to different prior competence of the students (e.g. by offering adjustment courses). The users/teachers of the module select a composition of the module which fits to their need. The OpenCoP (via its Curator/Configuration Manager) compose meaningful, pre-tailored configurations of the module by selecting and adapting sets of didactic formats which can be used to deliver the module.

The first step in module development is the definition of the competences to be acquired and the composition of target competence profiles for successful graduates. The underlying competence model (following EQR/ESG) should consider technical, professional, and global competences. The second step is the definition of target groups (e.g. students, professionals, executives) and the analysis of the competence needs and their prior competence profile. The third step is the selection of content and teaching/learning methods per competence. This is the point where the didactic formats come into play. The Instructional Design of the module is therefore a key element of the work of the OpenCoP. E.g., for the delivery of knowledge, (virtual) lectures, online courses, ebooks, distance learning etc. can be the right format. For the delivery of skills, projects, problem-based, case-based, and challenge-based approaches might fit. The scientific competences like analysis and reflection and the personal competences, e.g. ability and attitude, require additional didactic formats with a focus on individual competence. Project-based education contributes for team competences and can be used for the delivery of international, intercultural and interdisciplinary competence (3 x i). As a fourth step, the student journey of the module can implement different educational tracks, notably a Practical Track (with strong industry involvement), a more academic Scientific Track or an Entrepreneurial Track with a focus on innovation and business. The fifth step is to select the methodology for competence assessment (e.g. tests, delivery of projects, self-assessment, peer-assessment) and the credentials (ECTS, grading, professional certificates). The sixth step is the integration into curricula and human resource development (training) concepts which goes beyond the module composition (but influences it since overarching competences need to be considered, e.g. the OLOs of EIT). This includes the composition of educational packages (e.g. a 1 semester specialization/Minor/MA+ in a Master's) or complete educational programmes (e.g. Master's or Double Degree programmes). The seventh step is the Quality Assurance, including the concept for the evaluation of the effectivity (reaching the competence goals) and efficiency of the module, the learning trajectory and the didactic formats.

Table of Content

1. Introduction

This document serves as a guideline for teachers who are willing to create or transform their courses towards a digital education system. Evolution towards a full digital education provides several advantages over the traditional educational methods. One of the main advantages of digital education is the opportunity of implementing adaptive courseware, based on the individual knowledge and prior experience of the students, a concept which is called active learning [1]. Adaptive courseware allows for changing the learning trajectories for each student independently. By using online platforms, a learner's progression can be monitored more accurately and by providing constructive feedback at the right moments in time, their aimed competence growth can be verified and the remainder of the course can be adjusted to the actual knowledge of the learner (based on answers of previous assessments) [2]. For this, evaluation at the right moments during their course progression is mandatory. The digital system allows the teachers to identify possible difficulties for each student individually as the course progresses instead of the traditional situation where only the exam result reflects on the student's competence level. By live monitoring, problems can be identified well in advance, increasing the chances of succeeding the course. Research has proven that adaptive learning techniques increases the student satisfaction and it allows to spent more time on topics where students experience difficulties, whereas in traditional classroom lectures this is not (always) the case [3]. The structure of this document is shortly discussed next.

As in any course, first of all the expected competences should be defined. Those will influence the approach that can be used regarding the course material, course progression and evaluation methods. Secondly, the didactic (course) materials which are suited for digital education will be briefly discussed. Please note this is a non-limiting list. Next, a general description of possible evaluation methods will be given which depend on the type of outcome (digital or physical) and the way of assignment execution (individual or group).

A module can be defined on a long term (semester format) or for a short format (called block-weeks). The way in which the above described course materials and evaluation methods are implemented, differ for both of these approaches. Therefore, in the fourth section, the two types of course structures will be discussed and the relevant course materials and evaluation methods will be discussed. The final section describes how these approaches can be implemented in a digital environment, for instance Moodle.

2. Guideline for Module Development

The didactic concepts consider a toolbox of didactic formats (e.g. lectures, workshops, projects, case-based formats, etc.) and the methodology for the composition and orchestration of a competence development path, e.g. by conducting a module in an educational programme (EP). There is certain terminology which can be defined as follows:

- A competence development path is a sequence of steps which are done in order to acquire a certain competence, meaning to develop the competence profile of a learner from one state/level to another state/level.
- A learning trajectory describes the learning process of the learner while developing the competence. It is focussed on learning and didactics in a learner-centric view.
- A student journey is looking at the teaching and learning process from an organisational point of view, describing what the learner is doing when and where and with which methods/tools.

The module development considers 2 aspects for the competence development:

- The content which is delivered, meaning the knowledge, skills and abilities.
- The didactic formats which are used to teach and to learn the content.

Both content and didactic formats are selected, combined and put into a meaningful sequence in order to form the student journey of a module. The selection and orchestration depend on the learner (previous competence profile, competence goal, learner type, time budget, …). The module serves as a container for all required methods, tools and materials.

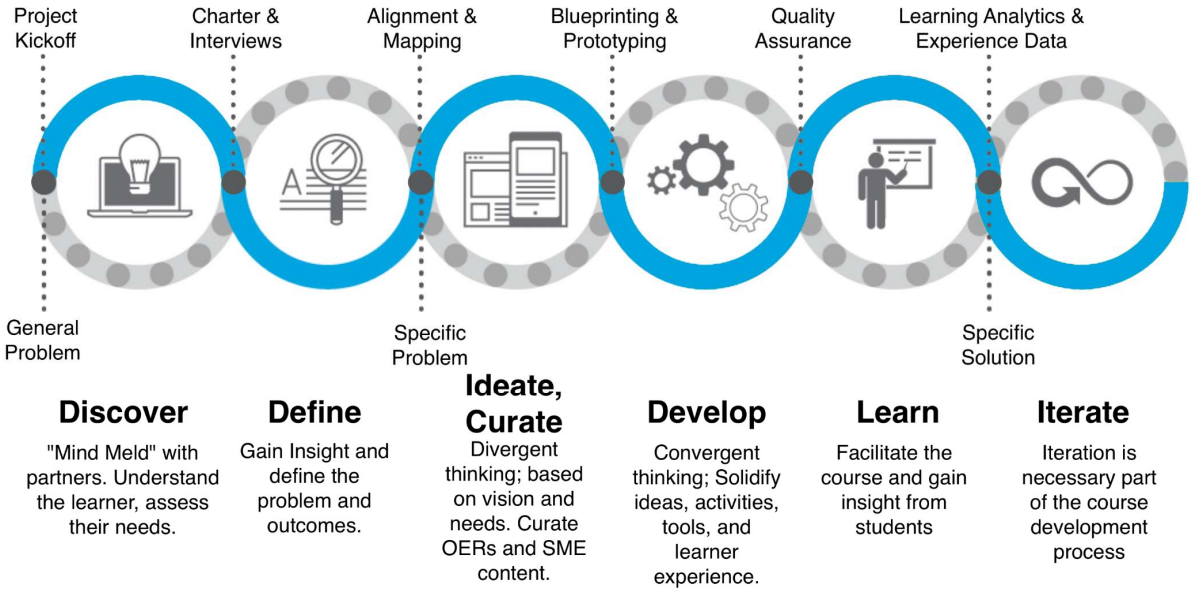

Figure 1: Design thinking in instructional design [7]

The Open Communities of Practive (OpenCoP, see “Specification: Open Community of Practice”) develop the modules based on this composition in an iterative process. The

developed material is provided in a Learning Management System (LMS, e.g. moodle) as an eLearning module serving as a tool box of educational resources and pre-tailored student journeys which can be used by teachers and learners to deliver the module. The iterative development process of the OpenCoPs specifies and develops versions of the module which are then delivered in pilot teaching and evaluated and improved based on the feedback. In Fig. 1, the steps of Discovery and Define are the entry point for the module specification. The steps of Ideate, Curate and Develop are the core of the module development. The Learn step is conducted in the pilot teaching and concluded with an evaluation leading to the Iterate step.

Figure 2: Instructional Design Cycle [Florida International University, Joshua Rees]

The module specification and development iterate the following 7 steps:

1. Define the competences which should be obtained by doing the module (see 2.1). This is based on a common competence model and the description of the prior competence profile and the target competence profile of the learners. The target competence profile is the course goal and defines the learning objectives. It is the basis for the assessment, too.
2. Analyse the target groups, meaning the future learners (see 2.2). This step is needed in order to define tailored student journeys and learning trajectories through the module, either individually per learner or for similar groups of learners.
3. Gather the content, select the didactic formats (teaching and learning methods) and develop the storyline of the module. This step involves choosing the design model and the design elements within the instructional design process.
4. Since the module should be adaptable for different learner groups it is advisable to define pre-tailored educational tracks, meaning student journeys that learners can follow. The most relevant ones are the practical track, the scientific track and the entrepreneurial track.

5. The competence development and the competence gain should be measured and controlled by doing competence assessment. Competence assessment is a highly complex task which goes beyond exams and tests. It has to be adapted to the competences and the target groups. The basis is formed by the definition of assessment criteria and the respective tools for measurement.
6. Integrate the module into educational programmes, e.g. by defining meaningful educational packages out of correlated modules and other elements (e.g. projects, theses).
7. Implement a quality assurance for the module development by getting feedback from learners, teachers and graduates, e.g. by a survey-based evaluation.

The Open Communities of Practice (OpenCoP) implement this module development process in an iterative cycle with a release of evaluated modules to the public. This module development cycle relates to the steps of the Instructional Design (see Fig. 2).

2.1 Competences

Competences are 'the ability to do something well' [4]. With this definition in mind, a distinction can be made between initial competences and final competences after completing the course/module. The concept of the adaptive courseware and active learning is to create a personalized educational path for each student in such a way that they can progress from their initial competence level towards the final competences in the most efficient way.

- Initial competences are those competences which are possessed by a student before attending the module. Those can be tested by using pre-modular tests, as will be described later in this text. By assessing those initial competences, individual learning trajectories can be created by using the concepts of adaptive learning techniques in such a way that the final competences can be achieved at the end of the series of courses.
- Final competences are those which should be mastered by a student after completing the module and should be evaluated in an appropriate manner based on the educational approach that was used. Those final competences should be defined for each module as they are the benchmark of what a student should have learned.

For the sake of consistency, the terminology proposed by the EQF will be used. The European Qualifications Framework divides competences in the following groups:

1. Knowledge – the ability of a student to reproduce theory / facts
2. Skills – the cognitive or practical ability of a student
3. Responsibility and autonomy – the ability of a student to apply the knowledge and skills to real-life situations

With regard to the concept of digital transformation, a fourth skill might be appropriate to be defined:

4. Digital skills [5] – the ability of a student to use digital tools to acquire the defined final competence levels

2.2 Target Group Analysis (to be done)

Target groups: students, professionals, executives

2.3 Didactic Formats

Evolution towards a full digital educational system will take time. Therefore, it might be useful, for existing courses, to use existing course material and try to adapt it gradually for online education instead of creating a completely new set of course documents. The target of this section is not to discuss how the different chapters of a course can be accessed by a student (this is part of course progression, which is discussed later). Only the course material itself is briefly discussed.

2.3.1 Traditional course materials

In current education (physical format, on-campus), the traditional learning materials consist of a textbook, slides and handwritten notes.

2.3.2 Digital education course materials

2.3.2.1 Handbook

Many people prefer a printed version of a handbook in which they can add notes and mark text. A simple way of providing this information is by distribution of a written book in .pdf format using the online platform (e.g. Moodle). A second option is distributing the book via publishers or book shops where it can be bought. This book can be used as a reference work and should contain all information for the student to be able to reach the final competence levels.

2.3.2.2 eBook

eBooks differ from traditional handbooks by being available only online. eBooks offer the opportunity to incorporate hyperlinks to additional exercises or information (like Wiki's, videos and so on). At the end of each chapter, hyperlinks could be provided which refer to an online test that should be completed before the next chapter of the eBook becomes available.

2.3.2.3 Online (live) lecture

Online live lectures are in principle identical to the traditional way of teaching. It's a form of (mostly) one-way communication where a teacher is narrating the course material which is basically already provided in both handbook and slides. Therefore, tis is one of the less suited methods for teaching an entire course. However, live lectures are very useful for providing extra information in case students have questions which they cannot answer themselves by looking into literature or the additional information that is provided by clicking on the icons of the interactive eBook. After each chapter, a small live session could be planned where students have the opportunity to ask questions to the teacher. However, this implicitly means that those

moments can be considered as ‘deadlines’ by which the students should have completed the courses regarding that chapter. The advantage is that this method can be used as a way to make sure that students are studying and following the courses of a module on a regular basis. Yet, the live ‘question’ sessions are not mandatory, so whether they attend these or not is their own choice.

2.3.2.4 Online (recorded) lecture

In a recorded session, a teacher follows the same procedure as a live lecture, but spread over multiple small videos. Staying focussed for two hours straight is close to impossible. The target is to keep videos as small as possible (e.g. 2-5 minutes). This form of education should be complementary with a live session now and then, in order to provide extra information where needed.

2.3.2.5 Presentation (without lecture)

A variant on the online live and recorded lectures, is to only provide the presentation itself without the teacher explaining every slide in detail. Instead, a similar concept to the already described eBook can be used where hyperlinks could be incorporated at multiple locations during the slides. For instance, when a difficult formula is being given, an icon can be shown which, by clicking upon, directs the student towards a page with the full derivation or additional information about the formula. It could be linked to a page in the eBook for instance to which the student can navigate automatically by clicking on the formula (or the icon next to it). Small videos (a couple of minutes) could be used as well to provide further explanation about a certain topic (but no full lectures). This requires the student to be more active while learning instead of just listening to somebody talking for a couple of hours.

2.3.2.6 Live chat options / forum

Especially for concepts like 2.3.2.2 (study with an eBook), 2.3.2.4 (recorded lectures) and 2.3.2.5 (presentation without lecture) it can be useful for the students to have the opportunity to ask questions while they are going through the matter. As mentioned before, live question sessions should be foreseen on a regular base, but sometimes only small questions arise at the moment. If students are capable of asking questions live and in a public way like a forum or a chat function in the online environment, others might notice this question as well, which provides several opportunities:

1) The students can help each-other out (a form of peer-teaching). Some students might have more experience on a certain topic compared to others, and the barrier between students mutually is smaller compared to the barrier between a student and a teacher. They might be able to figure out the problem themselves.

2) The teacher can follow the conversation and interrupt when it is noticed that a wrong explanation is given.

3) It’s an indication for the teacher on

a. The average course progression is (where are most of the students in terms of course progression compared to the timeline which was foreseen)

b. Problematic topics or complaints about certain aspects of the course (material)

4) In case a lot of students appear to have the same question, the teacher notes this and tries to:

a. Correct the course material in such a way that the explanation in the video/handbook/ presentation is more clear

b. Explain the problem during the upcoming live question session

Student forums exist for a very long time. However, the information that is given there is not always correct (lacking or wrong information). By allowing the teachers to follow live conversations, misunderstandings can be prevented.

2.3.2.7 Peer-teaching

In addition to the live forum where students can help each other out, lectures can be given on certain topics by students themselves. In international or interdisciplinary modules, each student can have a different educational background. These backgrounds (and their corresponding competence levels) can be estimated by using a pre-modular test (see later). Students can be asked to provide small knowledge clips on certain topics which they know a lot about in order to make the course material

a. Varied (not always the same teacher who gives explanation)

b. Interesting (everybody can share their own experience with own insights and remarks

It is however important to clearly describe whether this information that is being provided by students, is part of the ‘to-know’ of a certain course or not. Two options are possible:

- Evaluation of the students that follow the course. The additional information is part of the course material and can be evaluated in e.g. an exam where the knowledge competences are assessed.

- Evaluation of the students that are giving the information session. The additional information is not part of the course material for everybody following the course. However, this can still be used to evaluate the communication (and social) skills of the presenters.

2.3.2.8 Lectures given by industrial people (real-life situation)

Quite often during theoretical courses, the question arises what the practical use is of the matter that is being taught. People from the professional world could be invited to give small lectures / presentations which are related to some chapters of the course. This creates opportunities for evaluation as well, as these professionals can create small assignments (case studies) which are related to the real world (instead of ‘invented’ problems as is sometimes the

case in traditional examination). Students need to realize that their courses are related to reality and this could be a valuable option to make them aware of this.

2.3.2.9 Summary

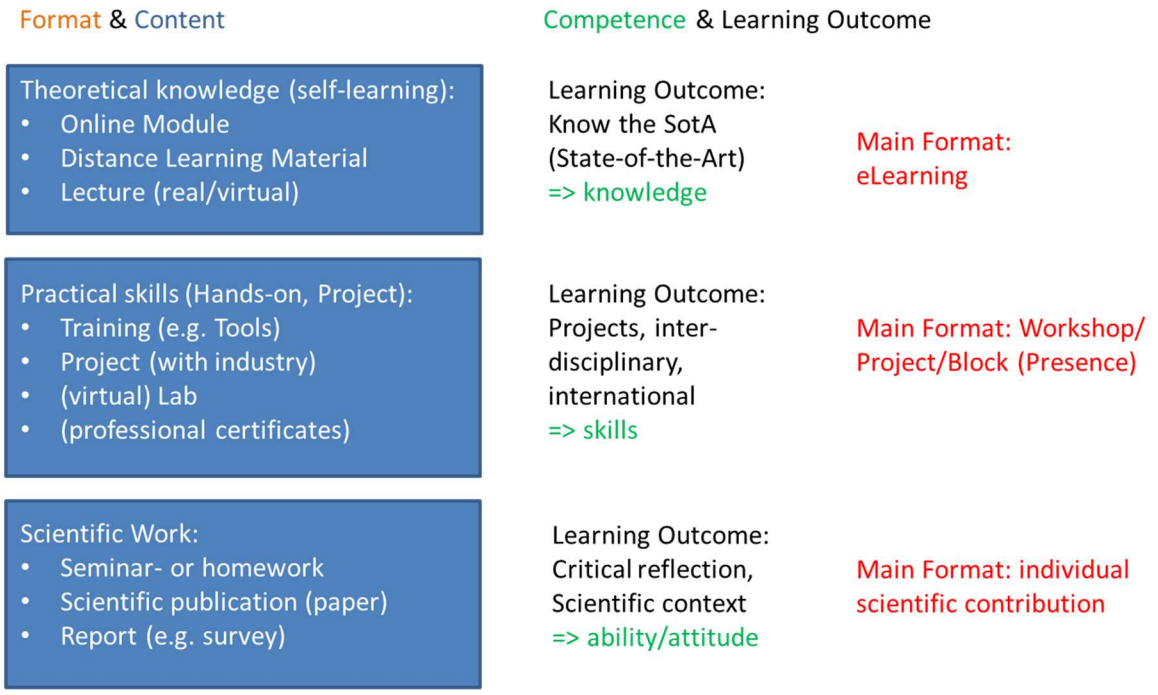

Figure 3: Mapping of Didactic Formats to Competence Areas [own illustration]

With the selection of didactic formats according to the intended competence gain, a move from teaching week centred to learning experience centred semester design will happen.

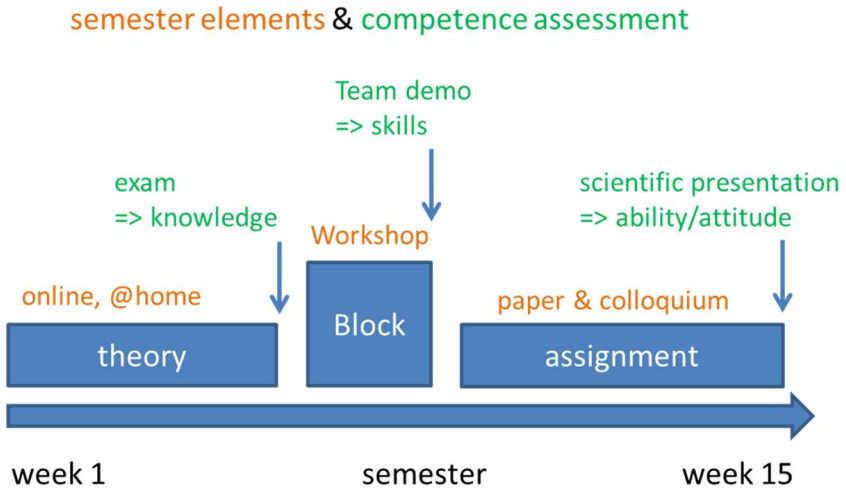

Figure 4: Scheduling Example of Didactic Formats during Semester [own illustration]

2.4 Educational Tracks

To be completed.

3. Module Implementation – Methods and Tools

3.1. Introduction

Now that the different didactic formats have been discussed, one can take a look at the two common implementations for a module: a block-week or a semester format.

A block-week is characterized by a limited amount of time where the core of the education is located on the skills and responsibility/autonomy rather than knowledge.

A semester format on the other hand has the ability to focus on all competence types.

Following situations could occur:

1) The course is developed so that it can be completed entirely within a block-week. This could be interesting, for instance, for an elective course abroad or for an introduction course on a certain topic.

Example 3D printing

Theoretically, it should be possible to develop a 3D printing module which can be fully covered within one week. Most people only know FDM/FFF as it is the most common form of 3D printing. In this case, the courses are focused on the basics where the first day is more theoretically oriented, discussing the materials, printer parts, influence of printer settings on the quality and so on. The next 3 days can be focused on hands-on, guided examples. The final day can be a group assignment where a part is given to the students which they should replicate. The way in which this can be evaluated (with or without the aid of digital tools), was already discussed in section 3.1.

2) The course is developed only for a semester format (traditional courses without block-weeks in between)

Example 3D printing

As the module is based on a long-term concept, much more details can be covered. One of the courses could be related to the different types of additive manufacturing. Besides FFF/FDM, also SLA, SLM, SLS, WAAM ... could be discussed. Another course could be specific on material properties of polymers, metals ... and yet another one on motion control and G-code. The theory (knowledge) can be assessed using traditional exams or tests, whereas the skills etc can be evaluated using an individual or group assignment where a part has to be created.

3) Both are combined where part of a module can be followed abroad whereas the core part will be followed on a long-term format at the home university/high school.

Example 3D printing

This option consists of a combination of the methods which were described above. The theoretical classes can be given within a semester program. However, students can chose for electives abroad. They can go to a campus which is specialized in FFF/FDM for instance and apply the knowledge which they have learned during the theoretical courses on their own campus to practical examples.

3.2. Block-week format

3.2.1. Definition of the competences / expectations

To be discussed

3.2.2. Pre-modular test

A pre-modular test in this case can be mandatory in order to be allowed to follow the block-week on a university abroad. Some options:

- The pre-modular test is required to be completed, but the result is non-binding. Whether or not the student has passed the test, the block-week can be started.
- A positive result on the test is mandatory to get access to the course. In this case, the student needs to pass the test before he/she/X can start the week. The advantage of this method is that the organizing university can be sure that the level of the candidates has at least a certain threshold, increasing the efficiency of the week without having the risk that some people flatten the learning curve of the entire group.

It also allows to identify the personal expertise of each candidate. In case peer-education is intended during the week, this can be useful. A student with a lot of scientific background can be selected for instance to give explanation on the 3D printing materials. Someone with a more entrepreneurial background could give an introduction on how to develop a business model and so on.

3.2.3. Learning methods

The number of virtual courses should be limited during this week. Either a live course or a lecture given by a professional person could work better. At the end of these lectures, a real-life case study can be given to the students (individually or in group) which they have to solve as efficiently as possible. As a theoretical backbone, a small document (guideline) can be provided which can be used by the students to solve the case studies. As in most cases, students should have followed at least part of the theoretical course before attending the week, they can obviously also use their standard course material added with extra documents to

guide them through the week. Presentations (slides), eBooks and handbooks in general are part of this.

3.2.4. Monitoring of the course progression

In case of a group assignment:

A daily report can be made by each individual team member in which they indicate the planned work and the work that has already been completed. This gives a short-term progress-report which can be submitted by the end of the week to check the teams planning capabilities and efficient way of working.

In case of an individual assignment:

An online survey can be completed after every day in which the students have to indicate, for instance, the amount of time they spend on the course that day, which tasks have been completed, ... Another important one is the ability for students to indicate difficulties. The teachers (supervisors) of the block week should monitor these messages every evening so that they can adapt the rest of the week, based on the feedback from the students. If they note that, during the first day, some difficulties arise regarding one of the topics which were explained, they can start the following day by a small recapitulation in order to make sure that everyone is on the same level. Providing additional course material is not the best solution on a short-term format, as there is simply not enough time. Personal feedback and help is the recommended solution.

3.2.5. Evaluation (competence assessment)

Competences can be evaluated by an oral presentation at the end of the week or a writing paper, a manufactured part or a program, together with peer-reviews etc (see figure 1). Due to the lack of studying time during one week, an exam at the end might not be the best solution for evaluating the knowledge. In case the block week would be mainly knowledge based (which should be avoided), the students could be evaluated by an exam. However, in that case, they should have enough time to process all information. The exam could take place, for instance, during the regular exam period at the end of the semester for which an online exam format is well suited.

3.2.6. Didactic evaluation (+ quality assessment)

Part of the didactic evaluation was implicitly mentioned under 4.2.4. The students should have the ability to mention problems using the online platform, which should be monitored by the supervisors. In case multiple students experience the same difficulties, this could be an indication of a problem with the way the matter is being taught. It is up to the teachers to note this problem and act on it instantly, for instance by re-explaining it the next day.

Secondly, a block-week is characterized by a lot of interaction. Teachers should make use of this by frequently asking the students what they think of the approach, how it could be improved. A questionnaire at the end of the week should be avoided, as most students experience this as ‘extra work’ resulting in no (or useless) responses.

An alternative to this could be the obligation to reply to some open questions before they can submit their final documents/data/presentation ... If they need to submit their work at the end of the week using the online platform, the first screen they see could contain some open questions on which they have to reply before they can continue to the submission page. In order to avoid useless responses, a minimum amount of characters (spaces, enters ... excluded) should be required so that they are obliged to respond in a meaningful way.

3.3. Semester format

3.3.1. Definition of the competences / expectations

Competences should be clearly described and grouped, based on the subdivision of the EQF:

- Knowledge
- Skills
- Responsibility and autonomy
- Digital

For each of the defined competences, an initial estimation of the level of the candidate will be established by completing the pre-modular test. The evolution of each of the competences can be followed throughout the trajectory of the student. By monitoring the evolution, the courseware can be adapted towards the student's needs.

3.3.2. Pre-modular test

A pre-modular test estimates the prior level of the candidates' competences. The main target of this test should be to adjust the individual trajectories of each of the students. The way these can be evaluated, depend on the parameters discussed in figure 1. It is up to the teachers to decide whether or not they make the result of the pre-modular test binding, meaning that the student should at least obtain a certain level before access to the course is granted.

3.3.3. Learning methods

All learning methods which were previously discussed, could be utilized for long-term digital education: handbooks, eBooks, online (live) lectures, online (recorded) lectures, (interactive) presentations (without lecture), live chat options/forum, peer teaching, lectures given by industrial/professional people (real-life cases). The key to keep students fascinated is using a combination of the earlier mentioned learning equipment rather than sticking to one and the same principle.

3.3.4. Monitoring of the course progression

In terms of active learning and adaptive courseware, course progression monitoring is an important aspect of the system. By monitoring a student's progress, problems can be detected in time and the trajectory can be adapted based on the students individual needs. A distinction can be made between parts of the course that have been followed (e.g. clips that have been watched) and tests that have been successfully completed. Monitoring the course progression

is closely related to the feedback system. In case a student is not on track, an automatic notification can be given to the teachers so that they can contact the student and provide help where needed. A graphical representation of possible student trajectories is given on the following page.

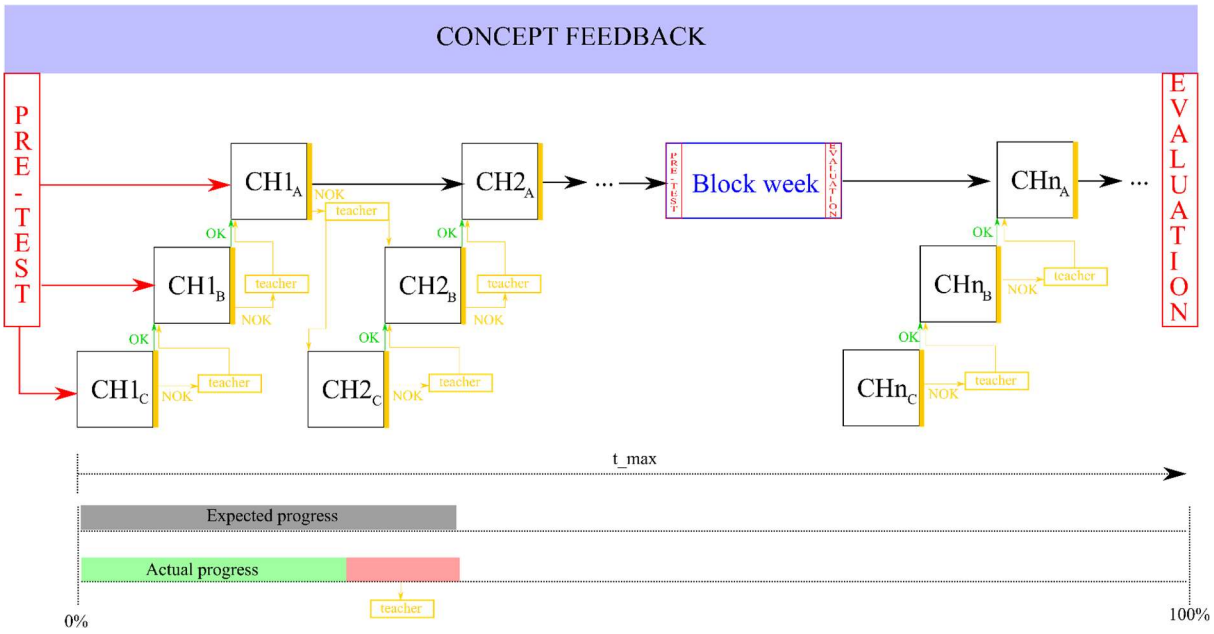

Figure 5: Flow Chart with possible trajectories [own illustration]

The module starts with a pre-test, estimating the prior competences of the student. The course has to be developed in such a way that different levels of course material are available. Chapter 1 covers the same content, but at different levels, depending on the knowledge of the student. CH_{1_C} has a lot of basic background information for those students whose level is too low to start with the difficult content of the 'A' version of this chapter. CH_{1_A} on the other hand, contains all advanced information and a more complicated test at the end. Assume worst-case scenario where the student has to start in chapter 1, grade C. After completing, he has to answer a couple of questions before being allowed to the intermediate level of that chapter. In case he passes the test, CH_{1_B} becomes available. In case the result is not sufficient, the system will inform a teacher who can contact the student for further information (providing extra documents or simply explaining something more in detail). The teacher can grant access to the next chapter manually once he confirms that the student has received more information and is capable of starting level B of that chapter. The concept continues until level A of that chapter has been completed. In case the result is positive, the student can continue with chapter 2A immediately. In case the outcome of the test of chapter 1A is negative, a teacher will be informed who will contact the student again. Together they can try to find the reason for

failing the test, after which extra information can be provided if necessary. The teacher can decide if the student should start in level C or B of the next chapter.

The course should be structured in such a way that the longest possible path (where the student has to complete all levels of all chapters) is still feasible within the time foreseen for the course. Also note that not all levels will take the same amount of time. Levels C and B of a course are generally the 'basics' and should be completed relatively easily.

In case a student gets behind on schedule (see lower part of the flow-chart), the teacher will be informed who will again contact the student for a discussion.

Feedback on the didactic concept covers the whole course, where students can give direct feedback, but also implicit feedback based on the results of the intermediate tests can deliver useful information for adapting the course material on the fly.

Assignments etc were not yet mentioned in the flow-chart, they vary based on the module.

3.3.5. Evaluation (competence assessment)

The competence evaluation methods were already discussed into detail earlier in this document. The most important aspect is to provide timely feedback to the students in case a problem occurs. The system can notify the teachers in case a student did not pass for a test at the end of a chapter, for instance, so that an additional chapter can be foreseen which should be followed first, before continuing the 'regular' chapter sequence. This was already schematically depicted in the flow-chart in Figure 2.

3.3.6. Didactic evaluation (+ quality assessment)

Didactic evaluation is related to the evaluation of the course material, lectures ... A traditional approach for this is to send out a questionnaire to the students who attended the course. This is however not the most efficient method because:

- Students often do not reply in an objective manner (or do not reply at all)
- The questions are often not applicable to the course that is being evaluated
- The scale for evaluating is often irrelevant ('more, a bit more, less, much less' are not good indicators as the person trying to answer the question has no clue what the difference is between 'more' and 'a bit more').

The best way for getting an objective idea about the appreciation of the concept by students is to get into a conversation and ask the feedback orally. This can be done, for instance, after an evaluation moment where the teacher talks to the student for a couple of minutes about what they appreciated and what should be improved. Some questions that should be answered (or deducted from the answers of students) are:

- How user-friendly is the platform?
- What did you think of the quality of the lecturers?
- The ability to stay focused during the courses
- The efficiency of processing all the information from different sources

- The concept of teamwork with people you have never met before (in case of online teamwork assignments)
- The quality of the course material
- How well the examination (way of evaluation) is in line with the courses that were seen during the semester
- ....

Aspects like the lecturers and the quality of the course material can be evaluated for instance after the mandatory tests at the end of each section/chapter. The feedback can be given immediately to the lecturer so that in case of serious issues, the clips and/or course material can be updated instantaneously. The advantage of monitoring all progress of the candidates in real-time is that it gives an estimation of how long it takes on average to complete the module (or individual chapters). By doing so, the question ‘how long did it take to complete the course in relation to the time foreseen’ can be answered quite accurately. Oral feedback can be asked for instance during the live question sessions, which were mentioned already a couple of times before. By doing so, the chance of obtaining useful feedback is increased without asking too much supplementary time from the students. An example of an end-of-semester questionnaire used by the University of Mississippi to evaluate the adaptive courseware is given in annex A [6].

4. Competence Assessment

Evaluation might be one of the most critical aspects related to digital education. Evaluation has to be described, based on:

1) The type of evaluation (peer, teacher or computer)
2) What type of competence is being evaluated (knowledge, skill or responsibility/autonomy)
3) The time of evaluation (the frequency)
4) The target of the evaluation (estimating the prior knowledge of a student during the pre-modular test, or assessing the final competences after completing the course)

4.1. The type of evaluation

Generally speaking, the evaluation of a student's competences can be done by either other students, a teacher or a computer. Which method is best suited, depends on two aspects:

1) Execution
    a. Individual
    b. Group
2) The outcome of the assessment
    a. Physical (object)
    b. Digital

Depending on the type of module that is being aimed at, several combinations are possible, which are graphically represented in the figure below.

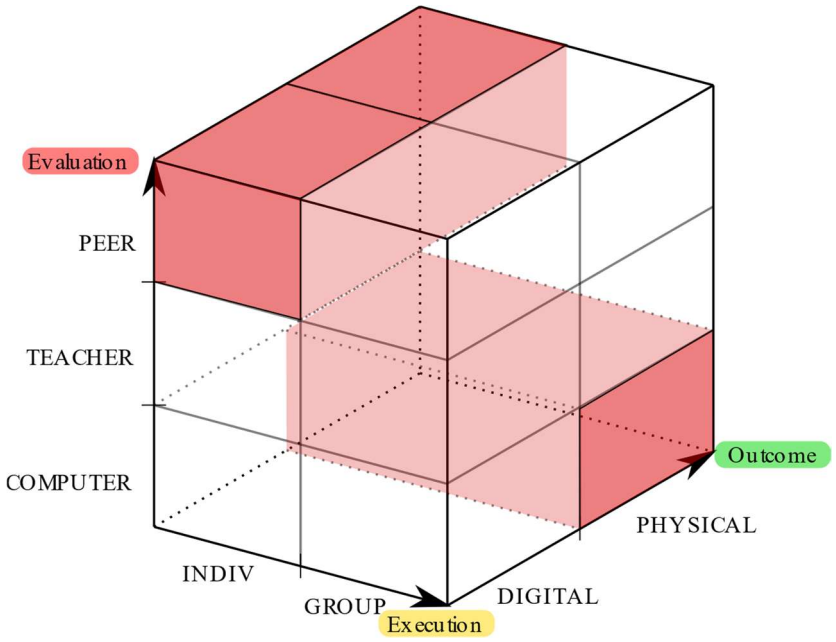

Figure 6: Graphical representation of the evaluation methods [own illustration]

Two zones are marked in red. This does not mean that those zones are impossible, but it might be a bigger challenge to use them.

a) Peer evaluation for individual assignments.

Within the content of this section, 'peer evaluation' refers to the evaluation of an assignment of a student by other students. The problem with peer evaluation on aspects that are not related to teamwork, is that peer evaluators often have the same level of experience as the student which is being evaluated. Teachers on the other hand are considered to have more expertise and can therefore judge a certain result in a more reliable manner. A second problem is the objectivity. People knowing each other very well will have the tendency of giving high grades to their colleagues, resulting in meaningless scores. A possible solution to this could be to anonymize the evaluation, but that will only work for large groups as in the case of small groups, it might be possible to derive the author of a file just by the way it is constructed.

b) Evaluation of a physical outcome (object) by a computer.

A physical outcome (assume an object that had to be made) is difficult for a computer to evaluate as will become clear from the 3D-printing example below. Visual inspection etc. requires complex camera setups and processing software, which is a) cumbersome for sometimes relatively small assignments, b) labour and software intensive and c) you still need people to operate the systems and so on. This is not the case for files (digital outcome) which can, in most cases, be interpreted by dedicated software and processed automatically.

An example: 3D printing of a phone-holder for a car

Depending on the expected execution format and outcome, the evaluation methods can differ.

Case 1: An existing part is given to the students. They have to measure everything and develop a CAD model. Afterwards, they have to develop a slicer file which has to be set up in such a way that the object can be printed with minimal material usage and optimal printing time.

In this case, the outcome is a (series of) digital file(s) as it is not required to actually print the object. Those files can be verified by a teacher or a computer or even fellow students. In case of digital verification (computer), the concept of a grading engine can be used [5]. This system compares reference files (which were produced by experts) with the files of the students. By doing so, the system knows, for instance, that the printing time in the reference file was 3700 seconds. By programming the software, one can assign points related to the printing time in comparison with the 3700 seconds. Everything below 3800 seconds can be the maximum score, everything between 3801 and 4500 can be half the score and so on.

Case 2: The students have total freedom in their design. The only guideline is that the final result should hold a phone of 'x' grams. They have to design and actually print the object, still keeping in mind minimal material usage and printing time.

This question is more difficult to be verified by a computer. Different designs might lead to different results. In case 1, the focus was more related to the printer settings (as the object was the same for each student). In this case however, the freedom of the design provides more complexity regarding the evaluation because the reference file (created by experts) is not necessarily the best solution. The creativity of a person, also of experts, is limited so maybe a student has other (better) ideas. The concept of peer- and teacher evaluation is better suited. This case is a good example of a case study which could be part of a block-week concept (see later).

4.2. What competence is being evaluated

4.2.1. Knowledge

A traditional way for evaluating knowledge is an exam/test which can be implemented in a digital environment. However, the type and amount of questions that can be used are restricted by the online platform. An example of question types and the consequences related to the online platform of KU Leuven (Toledo) are given in Annex B. Furthermore, attention must be paid as to avoid unwanted collaboration between students. The questions have to be adapted depending on whether an open-/ or closed-book method is adopted. A second option to test scientific knowledge is a paper assignment. The disadvantage of this is that the quality should be checked by an assessor (human) and therefore cannot (or is difficult to) be digitalized completely. There are systems that can track key words in an answer, but interpretation of the context is important as well. If the system is looking for an answer to the question 'describe the influence of an increased temperature on the material properties of a polymer' and the system only checks for the word 'viscosity', the answer is meaningless as the computer does not check for the word 'increase' or 'decrease'. And even if it would, there can be a problem if the student accidently writes 'increased' instead of 'increase'. Spelling checkers presumably exist, but it might become overly complicated to implement.

4.2.2. Skills

The way in which skills are evaluated, strongly depends on the type of skill that is envisaged. Digital skills, like Excel or Word, could possibly be checked in a digital manner, for instance by a grading engine as is described in [5].

Practical skills, like for instance creating things by hand, are impossible to evaluate online. Those still need to be assessed live ('on-campus')

4.2.3. Responsibility/autonomy

Those are considered to be 'the ability of a student to use the knowledge and skills'. Suitable ways to assess this type of competence is by using case studies. Case studies could be linked for instance to point 2.2.8. 'lectures given by professional people'. A second aspect to evaluate here is the ability to work together without interventions of a supervisor.

4.3. The time of evaluation

Within the scope of the active learning and adaptive courseware concept, evaluation should be a continuous process rather than discrete moments in time. Two moments in time can be considered as discrete points, being:

a) The pre-modular test in order to assess the prior competences (see 3.4)
b) The final evaluation (exam / assignment ...) in order to assess the final competence level of the student

However, the path in between can be considered as a form of evaluation as well. The students can be asked to answer short questions before they move to the next chapter in an online course. Although these answers are non-binding (they do not influence their final result) they have to answer them correctly before they can move to the next chapter so implicitly this is a form of evaluation where the result is not a score, but a 'ticket' to continue the course.

4.4. The target of the evaluation

Two options are considered here which are linked to the 'discrete moments in time' as discussed in the previous paragraph being a) obtaining an idea about the prior competences of the student or b) assessing the final competences of the student.

a) Prior competences → the evaluation methods used can be identical to the ones that will be used for final assessment. However, initially those are only considered to get an estimation of the level of the candidate before they attend the courses. Based on their initial level, their individual trajectories will be adjusted in such a way that their chances of acquiring the intended level at the end of the course are equal.
b) Final competences → those are exams / tests / assignments which are actually comparable to the evaluation of the prior competences, but in this case the level of the questions should be such that the intended competence level can be assessed in an objective, reliable and repeatable manner.

The target of the intermediate evaluation in between these discrete moments (the small questions at the end of each chapter) have another meaning:

- They give an idea about the individual progress of the candidate. The system can track whether or not they passed the test of a certain chapter, giving an indication on where the student's progress is situated, compared to the timeline which was foreseen for the course.

- They indicate possible difficulties. In case a lot of students answer a certain question wrong, this might be an indication that the explanation which is given in the courseware, might not be clear enough for them to understand the matter properly. The system can give notifications to the teachers in case a question is answered wrong, for instance, in more than 50% of the cases. It's up to the teachers to take the required steps to solve this problem (by organizing a 'live session' or adapting the courseware for instance).
- It allows for a live trajectory change. In case a student answers wrong on multiple questions that are related to the same topic, the system can easily note this and possibly adapt the following courses based on which matter should be given more attention.

Example 3D printing course

If, at a certain point, the student has to answer questions which are related to a) material properties and b) printer settings, it might be that the person is able to answer most questions on the printer settings, but they give the wrong answer on multiple questions related to material properties. The system can track this and notify the teacher for instance so that they can contact the student and possibly provide more 'live' information. A second option is that the system automatically selects an extra course part (which is not foreseen in the 'standard trajectory') that deals specifically with additional information on material properties. Before the student can progress to the next chapter, they must complete the questions related to the extra chapter on material properties. This concept is schematically depicted below.

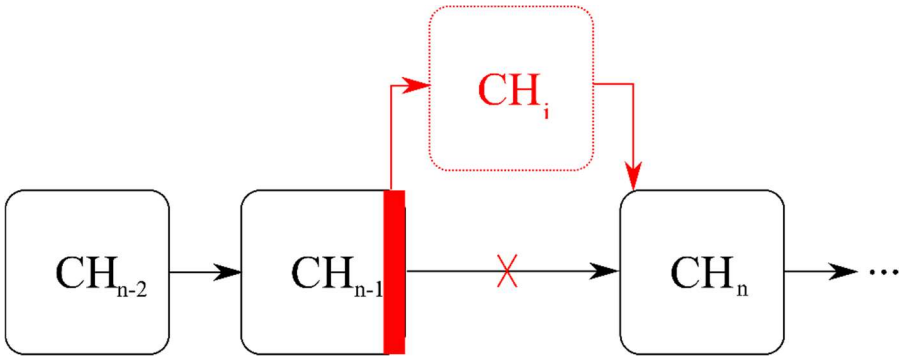

Figure 7: Black: intended trajectory,
Red: additional chapter after failed test of chapter $CH_{(n-1)}$ [own illustration]

4.5. Scoring method (quantification)

The scoring method also strongly relates to the target of the evaluation and the moment in time, as well as the parameters which were given in Figure 1 (evaluation by computer, peer, teacher; physical or digital outcome; individual or group assignment).

Based on moments in time

For testing the intermediate competences, most important is to provide feedback to the students, as was mentioned during the example on the previous page. In case a possible problem is detected, the student will get the notification that an additional chapter has to be followed, or they will be contacted by the teacher for further explanation.

Prior and final competences could be graded using

- Pass/fail (correct answer or not), especially useful for non-numerical questions
- Scores/credits

Based on type of evaluation, execution and outcome

Teacher and peer evaluation provide most freedom with regards to the possible scoring systems. The biggest advantage of these evaluation methods is the ability to provide feedback after a score has been given. In case a computer is used for evaluation, the software can only indicate which answer was incorrect and it an provide the correct solution, but it is not capable of providing an explanation ‘why’ the student’s answer was wrong.

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