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Master of Cyber Physical Systems

International Master of Science on Cyber Physical Systems

WP2: Development

D2.1 MS@CPS pedagogy

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1 Introduction

1.1 Abstract

The main goal of the MS@CPS pedagogy is to provide an orientation frame for the consortium wide teaching and the later MS@CPS continuation in the hands of the respective organizations. The content is a commitment of the consortium to a continuous improvement of teaching and as such the instructional methods deployed in the daily practice with the students and the needed preparation.

1.2 The purpose of this document

Education is a concept beyond borders and resentments, and so is learning. Even though still not decoded completely in the sense of the how of human learning happens in detail, several concepts spawned through the history of the research on learning that are considered universal either in their impact or in the outreach of their conceptualization. However, learning still has a local component, may it be continent, nation or area-wise, culture, upbringing and previous education forms and transforms how we learn and needs a special consideration. To cope with that beyond the development of education in general, each country and each university has their own lessons learned that are tailored to the individual needs of the region and the respective individuals who should be transformed into mature participants of the labour market or academia.

As the implementation of the MS@CPS program is also a story of inter-cultural exchange to enable one common language on CPS education, we see a paramount importance to highlight the local lessons learned on education, to not only lead to an active exchange on learning and teaching, but also to create a common understanding of the small differences that enable the successful implementation of MS@CPS in all participating countries. This includes respecting the local educational best practices, rather than enforcing educational practices, independent of the individual value of a given practice.

Therefore, this document should be guiding the process of a shared education as a white paper, creating a collection for guiding the educational process. As a white paper with a guiding nature will shed light on three sections to facilitate a cross-cultural education:

1. General overview of fundamental learning theories
2. MS@CPS practical pedagogy concepts
3. Experiences in participant countries as best practices
4. Best Practices and Commitments for MS@CPS Education

The overview presented here, will be a starting point and should be revisited throughout the course of the remaining months to be finalized along outcome D2.11.

1.3 Relation to other deliverables

There is an inherent relationship to D2.11, which is a pedagogy-based training according to best practices for educators. Furthermore, the practical pedagogy is application focused and will as such be considered for the planning of respective lab formats in D2.7.

1.4 Relation to work packages

WP1 collects the requirements of the overall curriculum building frame and delivers an input to the curriculum in terms of focused learning outcomes (LO) that can have a relationship to the application driven pedagogy parts. WP3 similarly collects and facilitates industrial requirements to the later study program and enables to fine-tune the practical pedagogy in a way to accommodate a range of specific industrial curricula integrations under one homogeneous concept.

2 Overview of Fundamental Relevant Learning Theories

A wide range of theories have been developed throughout the years to theorize on the concept and ability of learning, trying to derive usable concepts to improve the learning cycles for individuals and across groups of learners. Theories are created within and across different disciplines, being hosted in or borrowing from education, psychology, or mathematics to explain parts or complete systems of learning.

Millwood collected the main theories of learning in 2013[1] for the hotel project, where he focused on new concepts for technology enhanced learning. The overview splits theories into “key concepts”, “learning paradigms or world views”, “learning theorists” and “scientific disciplines”, exploring the different relationships and enabling to get a domain and theory driven perspective on the specific concepts. An overview of the collection is given by the mind map shown in Figure 1.

Out of the pool of different theories, two main ones are especially relevant to reflect on the perspectives of education and learning:

- Behaviourism, focusing on learning as a response to a stimulus.
- Constructivism, focusing on that knowledge is constructed by the learner.

Additionally, a closer look is given on Connectivism, as a modern perspective on education and learning, seeing the learner as learning in and through a network of information, which can be utilized as a narrative and algorithmic perspective for technology driven extensions to education.

[1] Richard Millwood. (2013, April 30). Learning theories map. http://hotel-project.eu/sites/default/files/hotel/default/content-files/documentation/Learning-Theory.pdf

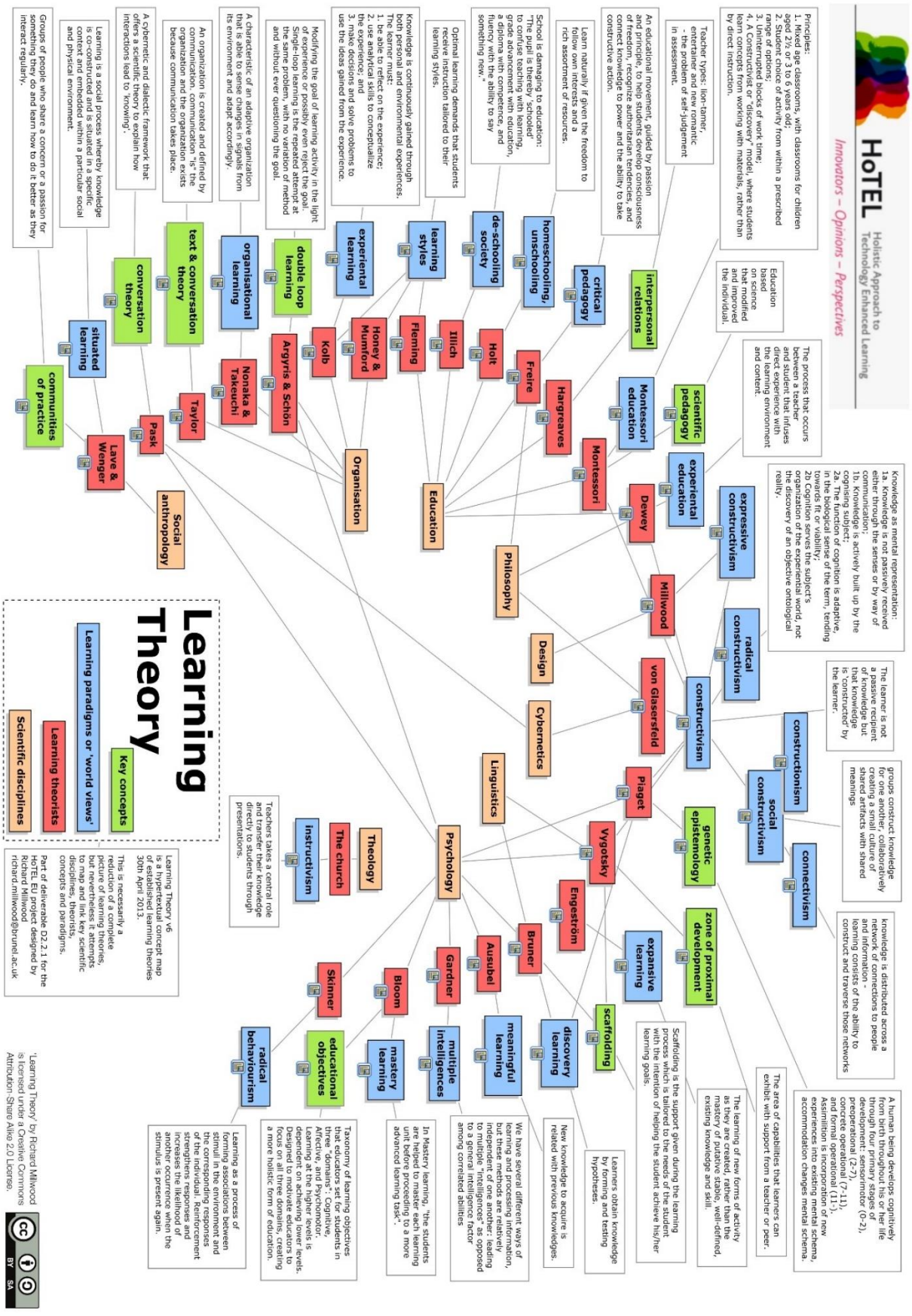

Figure 1: Learning Theories, following Milwood, 2013.

2.1 Top Down and Bottom Up Perspectives on Education

While the discussion on how to provide the best education is diverse and in continuous motion, one general question persists as a steady consideration, introducing two general perspectives on preparing educational instructions: how should education be provided as - top-down, starting from the general and highlighting correlations or as bottom-up, teaching the specifics first and introducing the topic's fundamentals, as reflected in (Weber and Vas, 2016[2])?

In a class room situation for a top-down approach a teacher tries to give a general overview at the beginning, introducing the big picture paired with an overall motivation, content- and outcome-wise, showing the correlation between the aspects of the particular field and immersing the students in a way which triggers the personal motivation to learn and master an area. Following the example of De Grauwe (Grauwe, 2010[3]) in the context of Macroeconomics, addressing the top-down approach from a system point of view, a top-down system is a system in which respective agents understand it fully. They are capable to see the system as a blueprint in which they can optimize their actions. An alternative understanding would be to see the system as a building which can be represented by its blueprint which is understood by its architect.

Contrasting to a macro-first top-down approach, a bottom-up way of teaching tackles the details of a specific topic area first to piecewise develop the topic towards the understanding of the whole area. The content focus is on teaching and mastering facts and rules and it is important to understand the detailed parts of the overall picture as building blocks which create the whole picture. A bottom-up approach is an instructor-driven approach and it aims to break down the complexity of an area and simplify the learning process through mastering the details first, making use of memorizing and repetition. Following further the example of De Grauwe, taken from a system perspective, in a bottom-up system, individuals understand only parts of the system. The system then works by applying simple rules on the individual level, together creating the whole system, which in this way resembles the behaviour of natural systems.

Strongly interwoven with the consideration of a top-down and bottom-up education is the comparison of behaviourism- and constructivism-based learning. A bottom-up education is here favoured by the concept of behaviourism, which is based on studies on animal behaviour and the response to rewards and punishment, while top-down education aligns with the concept of constructivism, which understands learning as a process of connecting new knowledge to previous learned knowledge. As both pairs of concepts are related, contrasting top-down against bottom-up teaching and behaviourism against constructivism is in many situations a proxy for each other.

2.2 Behaviourism and Top-down Education

As summarized by Ertmer and Newby (Ertmer and Newby, 2013[4]), behaviourism makes use of the concept of stimulus and response. Learning, following behaviourism, occurs when a learner gives an adequate response to a presented stimulus. E.g. while showing a learner a specific math problem, the problem represents the stimulus, while the fitting answer of the learner is the response. The key

[2] Weber, C., & Vas, R. (2016). TOP-DOWN OR BOTTOM UP: A COMPARATIVE STUDY ON ASSESSMENT STRATEGIES IN THE STUDIO ADAPTIVE LEARNING ENVIRONMENT. Proceedings of the European Distance and E-Learning Network 2016 Annual Conference, 41–49.

[3] Grauwe, P. D. (2010). Top-Down versus Bottom-Up Macroeconomics. CESifo Economic Studies, 56(4), 465–497. https://doi.org/10.1093/cesifo/ifq014

[4] Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, Cognitivism, Constructivism: Comparing Critical Features From an Instructional Design Perspective. Performance Improvement Quarterly, 26(2), 43–71. https://doi.org/10.1002/piq.21143

question of behaviourism is then how to strengthen and sustain the association between the stimuli and a successful response. Furthermore, the long-term goal is to foster positive responses by adding reinforcements to positive responses.

The proof of the positive effects of positive and negative reinforcements goes back to the experimental work of Skinner (Skinner, 1974[5]). Following the theory, the learner is characterized as reactive to the conditions of learning rather than active, weighting the environment higher than the inert and active motivation of the learner.

Teaching in this framework takes a strong emphasis on preparing and controlling the arrangement of stimuli and the consequences of given responses. Furthermore, the learner is continuously assessed to recognize where to start the instruction and to detect which reinforcement actions are effective for a specific learner. For transferring learned knowledge to new situations, learners are expected to generalize situations, with features shared or similar to previous learned behaviour.

Organizing teaching in the frame of behaviourism, emphasis strategies which improve the linking between stimulus and response with methodologies like reinforcement and practice. Learning happens through making use of recalling facts, generalization, association of explanations and performing/repeating learned procedures. Furthermore, it is recognized that behaviourism is not suitable to explain higher level skills and processing.

2.3 Constructivism and Bottom-up Education

Furthermore, summarized by Ertmer and Newby (Ertmer and Newby, 2013), constructivism "is a function of how the individual creates meaning from his or her own experiences". Constructivism envisions the mind as a filter, which filters the world to create its own reality. In this regard, the mind is conceived as the source of the derived meaning. The knower constructs a reality or interprets it, based on his or her perception (Jonassen, 1991[6]). Following Jonassen, the knowledge is constructed as a result is based on previous experience, the mental structures, and beliefs a person uses to interpret objects and events. E.g. in a classroom situation a teacher would introduce the general problem to solve and give the question of methodology to the learners for reflection and construction of their own methodologies in favour of connecting to their previous experience to only then advancing to the detailed methodologies.

The concept of constructivism, as collected by Perkins (Perkins, 1992[7]), goes back to the seminal work of Piaget (Piaget, 1954[8]) under the influence of cognitive psychology, guided by researchers as Bruner and Neisser and Goodman. In contrast to the view of behaviourism, constructivism takes the view that the knowledge of a learner is mind dependent and has to be mapped onto a learner. It receives ongoing attention since then and is used to observe and reason on learning as an experience driven function, creating meaning based on new and previous experience.

Teaching in the frame of constructivism takes an emphasis on practical involving the learner in situations which are embedded into a meaningful context. Understanding is strongly connected to the number of experiences collected in the context of the target education, where the learner develops ideas

[5] Skinner, B. F. (1974). About behaviorism. Vintage.
[6] Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? Educational Technology Research and Development, 39(3), 5–14. https://doi.org/10.1007/BF02296434
[7] Perkins, D. N. (1992). Technology meets constructivism: Do they make a marriage. Constructivism and the Technology of Instruction: A Conversation, 45–55.
[8] Piaget, J. (1954). The construction of reality in the child (Vol. 82). Routledge.

to master the situations. Learning and the transfer of knowledge always takes place in a context in the view of constructivism and the different contexts offer different links to the knowledge to learn.

To organize teaching in the scope of constructivism the teacher focuses on telling the story of a task, rather than setting the structure for the learning of the task. Bednar, Cunningham and Duffy argue in this regard that *"information cannot be remembered as independent, abstract entities"* (Bednar et al., 1991[9]). Learning in the frame of constructivism does not happen by learning and following a set of rules and strategies. The learning and effective use of knowledge comes results from using the acquired tools in real world situations.

2.4 Technology Driven Ways to Learning Theories

In contrast to the clear separation of learning theories for a promotion of learning, rather than teaching following a specific theory, the conscious selection of a theory by the teacher for a specific learning situation is crucial. The set of selectable learning theories is wider than the top-down and bottom-up or behaviourism and constructivism and includes further theories as cognitivism and recently connectivism and offer alternative views on the theories with the concepts of objectivism, pragmatism and interpretism. Resulting, the question arises if a learning theory is regarded as the leading theory and if none is leading which theory to select at a given time – moreover considering new developments in learning environments like the rising impact of technology and especially information systems.

An alternate view on the question of a selection of learning theories for learning environment is given by one of the most prominent citations for the use of constructivism, taken from the seminal work of Bednar, Cunningham and Duffy (Bednar et al., 1991):

> *"Instructional design and development must be based upon some theory of learning and/or cognition; effective design is possible only if the developer has reflexive awareness of the theoretical basis underlying the design."*

While the citation is taken as a strong emphasis for constructivism by the constructivism community, Duffy corrects this image in an interview ("Interview with Thomas Duffy," 2000[10]):

> *"It seems quite logical to me that no one is going to design instruction that they think will be ineffective--or counterproductive to learning. If they are acting in a way that they believe will promote learning, then they must have some notion of what learning is all about. […] Besides acknowledging this particular point, we were simply arguing that it would be worthwhile for designers (and educators in general) to become more aware and better able to articulate their views."*

Duffy underlines here, in contrast to a default learning theory selection, the importance of the awareness of the designer in the process of instructional design, rather than the selection of one and only one learning theory.

In this regard the awareness of the concepts and tools for teaching maybe sufficient, but a thorough and conscious instructional design is mandatory for the learning success. A careful and purpose- and situation-fit selection and modification of a learning theory outweighs the defaulting to one singular learning theory. Siemens emphasises in his seminal work about connectivism (Siemens, 2005[11]) the

[9] Bednar, A. K., Cunningham, D., & Duffy, T. M. (1991). Theory into practice: How do we link. In T. M. Duffy (Ed.), Constructivism and the technology of instruction: A conversation (pp. 17–34). Routledge.
[10] Interview with Thomas Duffy. (2000). http://www2.gsu.edu/~wwwitr/interviews/duffy.htm
[11] Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning. http://er.dut.ac.za/handle/123456789/69

definition of learning of Driscoll (Driscoll, 2005[12]) *"a persistent change in human performance or performance potential" that "must come about as a result of the learner's experience and interaction with the world".* As Siemens notes this definition *"encompasses many of the attributes commonly associated with behaviorism, cognitivism, and constructivism"* (Siemens, 2005).

Seeing learning and learning theories from this general perspective even a hybrid solution for organizing learning environments can be feasible and effective if designed carefully. For an insight into the possible methodologies and tools a second look onto the aspects of behaviourism and constructivism are valuable. A comparison of behaviourism and constructivism is given in ***Table 1***, based on the classification by Schunk (Schunk, 1991[13]) and the elaboration and extension of Ertmer and Newby (Ertmer and Newby, 2013).

Table 1: Comparison of behaviourism and constructivism, based on the classification by Schunk (Schunk 1991) and Ertmer and Newby (Ertmer and Newby 1993).

	Behaviourism	**Constructivism**
How does learning occur?	Learning occurs when a proper response is given following the presentation of a specific environmental stimulus.	Learning is the process of creating meaning from experience. Learners build an interpretation of the world based on individual experiences and interaction.
Which factors influence learning?	The arrangement of stimuli and consequences is the most important factor. Environmental conditions are emphasized before learner related aspects.	Learner and environmental factors are important and the interaction between both creates knowledge. Learning happens in a situational context and it is important in which situation the knowledge is used.
What is the role of memory?	The role of memory is neglected by the behaviourism.	Constructivism isn't focused on memorizing particular facts. Understanding is developed based on continues use of knowledge in specific situations. Learning needs the factors activity, concept, and cultural context.
How does transfer occur?	Transfer to an application is the result of generalization.	Transfer is reached by involving the learner in authentic tasks linked to and within meaningful contexts.
What types of learning are best explained by the theory?	Strategies of learning are important which strengthen the stimulus-response associations. The learner performs in situations of learning involving discrimination, generalization, association, and chaining.	Learning is always observed in a specific context and in conjunction with a specific content. Constructivism is most effective for advanced knowledge acquisition while initial acquisition is better supported by behavioural or cognitive approaches.

[12] Driscoll, M. P. (2005). Psychology of Learning for Instruction. Pearson Allyn and Bacon.
[13] Schunk, D. H. (1991). Learning theories: An educational perspective: Vol. xi. Macmillan Publishing Co, Inc.

What basic assumptions / principles of this theory are relevant to instructional design?	• producing observable and measurable outcomes in students • pre-assessment of students to determine where instruction should begin • mastering early steps before progressing to more complex levels • use of reinforcement to impact performance • use of cues, shaping and practice to ensure a strong stimulus-response association	• emphasis on the identification of the context in which the skills will be learned and subsequently applied • emphasis on learner control and the capability of the learner to manipulate information • need for information to be presented in a variety of different • ways • supporting the use of problem-solving skills that allow learners to go "beyond the information given" • assessment focused on transfer of knowledge and skills
How should instruction be structured to facilitate learning?	The instruction is structured around presenting the target stimulus and providing opportunities for the learner to practice to give the proper response.	Instruction has to be designed to show students how to construct knowledge, give multiple perspectives for specific problems. The designer of the instruction has to instruct how to create meaning and how to monitor, evaluate and update constructions. Further the designer has to design experiences for the learner with relevant contexts in which a task can be experienced.

The comparison of ***Table 1*** underlines the different trends of behaviourism and constructivism learning theories: behaviourism as the top-down, decomposing, fact oriented learning theory which is focused on stimulus/response pairs and constructivism as a bottom-up, generalizing, context oriented theory which is focused on linking experiences to new situations.

2.5 Connectivism as a Network Driven Theory for Learning

Cognitivism, in contrast to constructivism and behaviourism, is a more technology and network-oriented theory. It focuses on knowledge as symbolic mental constructs within the learner's mind, while learning stores the symbolic representations to the learner's memory.

Yet – as Siemens addresses (Siemens, 2005) – the majority of learning theories conclude that learning occurs inside a person only and fail to address learning outside of learners as technology-based learning. Additionally, existing theories do not tackle personal and organizational learning within organizations and neglect to assert the value of what is being learned. Seizing these limitations, Siemens collects seven questions not yet addressed by current learning theories, especially taking into account the shift to a new technology enhanced society (Siemens, 2005) (p. 3):

- *"How are learning theories impacted when knowledge is no longer acquired in the linear manner?*
- *What adjustments need to made with learning theories when technology performs many of the cognitive operations previously performed by learners (information storage and retrieval).*
- *How can we continue to stay current in a rapidly evolving information ecology?*
- *How do learning theories address moments where performance is needed in the absence of complete understanding?*
- *What is the impact of networks and complexity theories on learning?*
- *What is the impact of chaos as a complex pattern recognition process on learning?*
- *With increased recognition of interconnections in differing fields of knowledge, how are systems and ecology theories perceived in light of learning tasks?"*

Considering these questions, Siemens proposes a new learning theory – connectivism (Siemens, 2005). In the new connectivist vision, within the digital age, learning cannot solely rely on personal experience anymore but rather is derived as a competence from forming connections. Facing the speed and need of the technology enhanced society, the learner cannot experience every situation and borrows the experience from other people as their collected knowledge.

Connectivism strengthens the view that learning is motivated by connectivity, connecting experiences but also external information, residing in external, potentially interconnected, sources. Learning occurs in environments with shifting core elements – potentially outside of the learner's control – connecting specialized information sets and focusing on connections while connections which offer the learner to learn more are more important than the current state of knowledge. Connectivism fosters the understanding that decisions are based on changing foundations and stress the importance of the ability to differentiate between important and unimportant information.

In this vision, parts of different learning theories can be used for an instructional design with different viewing angles, if a conscious, consistent, and sustainable conception is used for the long-term design of a specific learning environment. A technology enhanced environment is sure to have to be considered as an influence in the conception of learning but it could also act as a game changer using the technology directly for learning and furthermore for testing, implementing a well-designed process as a middle way to the current learning theories.

Following the ideas of Siemens and Downes, what is learned is always connected to internal or external sources of information and has to be considered in a situational context and the context of connected information. Siemens concludes in this regard *"The pipe is more important than the content within the pipe"*. There is no proof for this assertion yet but the connection to information is increasingly important and can on the long-term proof to be more crucial than single information accessed through a connection in a specific situation. A technology enhanced environment therefore has to be aware of connected information, while the instructional design should be aware of the application "situation", reflecting the situations for which the learning is targeted and the technological environment in which the learning occurs.

3 MS@CPS Practical Pedagogy

Coined by Lee and Seshia - two of the main contributors towards the definition of cyber-physical systems - in 2011:

> *A Cyber-Physical System (CPS) is an integration of computation with physical processes. […] As an intellectual challenge, CPS is about the intersection, not the union, of the physical and the cyber. It is not sufficient to separately understand the physical components and the computational components. We must instead understand their interaction.*

The interaction and intersection of relevant domains for CPS education is what has to be thought through and revised. It needs not an interdisciplinary but cross-disciplinary discussion and readjustment of theories and assumptions in the respective fields, to enable a homogenisation that is currently not yet available. This task is yet a work of the future, requiring a change in the disciplines that is currently only happening in the research-oriented spaces and not yet part of the existing education. This change cannot be done overnight without extensive revision of our up-to-date education. Nevertheless, current educators can facilitate the right enabling changes already now and explore the intersection of domains in practical spaces. Such practical spaces can span more than one lecture in a practical, project-driven explorative lab environment in collaboration with multiple educators and incorporating up to date industrial requirements, in corporation with the industry.

Following this lead and in line with the commitments of the original MS@CPS proposal, MS@CPS will make use of practice-oriented design case studies as a methodological framework for developing advanced CPS knowledge. The proposal defines two methods which are at the core of our pedagogy:

- “Design and development case studies” (DDCS)
- “Courses in Practice" (CiP)

3.1 Design and Development Case Studies (DDCS)

The initial proposal defines **“Design and Development Case Studies (DDCS)”** as consisting of three phases, designed in cooperation with industrial partners:

(1) Offering descriptions of the interconnected practices: An analysis will describe existing tools, linkage, communication, and their usage. Such documentation is directed to a certain problem or needs statement.

(2) Designing case studies describing the realization from a product as well as from a process perspective: Including a description - of the knowledge engineering process, stakeholders, devices, and constraints as real-time requirements or big data considerations. A focus will lie on how changes in communication practices have been anticipated and how they influenced the design of advanced systems (**bridging different science domains**).

(3) Designing case studies that document the introduction, appropriation, and potential re-design of system artefacts in their respective domain of practice. Such documentation allows analysing the impact of learning mechanisms, functions, and design options within a distributed system.

In that sense DDCS resemble **Case Studies,** as coined e.g. for teacher education in the seminal work "**Using Case Studies to Enhance Instructional Design Education**" by Ertmer and Russel in 1995[14]:

> *"Case-based instruction is a teaching method which requires students to actively participate in real or hypothetical problem situations, reflecting on the kind of experiences naturally encountered in the discipline under study."*

In line with the work of Wasserman in 1994[15], a good case study consists of four core components:

1. *A case report*
2. *Study questions*
3. *Small group work*
4. *Whole group discussion*

Reflecting in the light of classical case studies and the special focus on cross-disciplinary cases, the intended three stages of DDCS can be translated in this way:

(1) Offering descriptions of the interconnected practices: Requirements Analysis of the is-state

(2) Designing case studies describing the realization from a product as well as from a process perspective: Collect factors and requirements, gather expectations how the involved science fields combine and interact.

(3) Designing case studies that document the introduction, appropriation, and potential re-design of system artefacts: Implement the case study and document it and the interplay of methods/fields involved.

At the core of the DDCS is the close handshake with up-to-date industrial requirements and research to enable the exploration of the CPS high-tech and high-research context, based and focused on a practical setup.

Very much aligned to the experience-oriented perspective of constructivism, students and teachers can use such practical spaces to revitalize the learned lessons in the lectures in an exploration of open ended, use-case driven topics. Extending on that, problems are tackled in groups of students, integrating discussions as a vital component of the problem-solving process. The teacher takes the role of a moderator, coming into action only if it is needed and supports the thinking processes, or is adding another perspective to render solutions truly cross-cutting and therefore CPS focused. In this sense, the approach is intended to borrow from the overarching concept of flipped classrooms.

To ensure the relevance of topics and problem cases with a shared research and industry perspective, it is needed to stay in close contact with the targeted industries, in a local and international context. To support this special need, the DDCS method is completed by a "Courses in Practice" (CiP) approach.

[14] Ertmer, P. A., & Russell, J. D. (1995). Using Case Studies to Enhance Instructional Design Education. Educational Technology, 35(4), 23–31.

[15] Wassermann, S. (1994). Introduction to Case Method Teaching. A Guide to the Galaxy. Teachers College Press, Teachers College, Columbia University, 1234 Amsterdam Avenue, New York, NY 10027

3.2 Courses in Practice (CiP)

As well here, the proposal is providing an initial definition of Courses in Practice (CiP). CiP is a practice-based learning and teaching approach, in terms of reflecting and replicating the daily engineering work which is representative for an industrial application and the industrial employment.

CiP follow three major goals:

- Courses in Practice are developed to be a didactical concept which **bridges between academic education and companies**.
- The CiP approach **focusses strongly on the industrial collaboration and interaction**, where companies define **market relevant projects** close to their core business.
- Students will work then in teams to **solve the envisioned projects inside of the companies** or in a simulated work environment in the research institutions.

CiP is much more a vision than a method. A vision for practical interventions within the curriculum, which are much closer to the industrial needs and are created with an active industrial involvement. The frame and method to create such interventions are free and unrestricted, as long as the intervention respects the goals and principles of CiP.

To facilitate this, the industry should not only be part of the problem or domain space but be part of the education. Thus, the industry should define relevant practical cases and participate in developing solutions to explore CPS education jointly. To do so, a close collaborative connection has to be built to the local industries, for each MS@CPS hosting university. To enable an interlinked approach, associated partners within the industry were invited and approved to support the project development and the later educational implementation.

The vision of the CiP idea is to put the involvement of the industrial partners into the centre. Classic use case driven approaches for practical sessions within master studies, already focus on solving tasks which are relevant for industrial applications. As such, the use cases are informed by the industrial requirements. However, they are usually decoupled from an active industrial interaction. CiP motivates to go one step further. CiP is about creating use cases but creating them in such a way that the industry is actively involved in the definition, the student's exploration of the cases and finally in solving of the inherent questions of the use case. This way it becomes possible to feed back the gained insights into the industrial application and furthermore into the education, as all needed stakeholders are participating in the CiP.

To do so, special collaboration schemes and course schemes are needed to enable the student/industry interaction over the specific use cases, while incorporating the teacher's support through moderation, goal-oriented scaffolding and mentoring of groups and individuals. Multiple new forms of interaction formats were developed throughout the years. In computer science related domains, hackathons are a recent format where practical problems are explored in teams that are created on demand from an open group of participants to solve a given problem by developing software within a time frame of one to three days. In many of such events the problem definitions originate the industrial, as well as the event being cosponsored, accompanied, and oriented towards industrial partners. Completing this frame with teacher support and placing it at the intersection of the curriculum topics makes it into a CiP intervention.

However, to ensure a long-lasting effect on the education, further communication and agreements are needed to spawn a self-sustaining application driven dual learning community. The MS@CPS project defined three hooks to ensure the implementation and application of the CiP vision:

- An early integration of industrial stakeholders in respective actions of WP1 and WP3.
- The implementation of an entrepreneurship track with a focus on educating and incubating equally to plant a seed for a mid-term enhanced start-up community.

- This CiP vision itself, as a long-term motivation to implement a stronger interaction between industry and research for the goal of organizing and changing the practical university education.

To reach the intended exposition within the studies. Both approaches, DDCS and CiP have to be seen in combination and interaction.

3.3 DDCS and CiP Fusion and Curriculum Recommendations

There is an inherent shared logic in the DDCS and CiP approaches. Together both methods are following a sequential rational:

1. Extract a specific need/**case from the industry**.
2. Then "**Design and develop(ment) case studies**" (DDCS)
3. … and put them into action through "**Courses in Practice**" (CiP) by working through the cases **inside of the companies** or in a simulated work environment.

The later implementation stage can be facilitated in a lab environment or within an industrial setting. It is intended to be followed up continuously, ranging from lab sessions, to seminars, to project works and finally the master thesis writing, aligning the different practical experiences and enabling to provide a long-term value-added perspective for respective industrial partners to sustain the collaboration.

Multiple recommendations can be derived from the envisioned three stages, utilizing the two methods DDCS and CiP for the continuous planning of the MS@CPS curriculum. However, the direct implications can be captured like this:

Implement Different Supporting Instruction Types

- Implement lectures with practical tasks – e.g. in an application module –, based on industrial cases:
    - Solve them simulated in the class, utilizing:

      labs, term papers and interactive seminars
    - Solve them in companies, utilizing:

      internships, industrial workshops and start-up incubators or contests

Implement the Strong Fusion of the Respective Domains of CPS:

- Create courses which combine two or more modules to "play out" the fusion of different fields within the CPS as **"cross-cutting actions"**.
- Support those courses with project focused formats.

4 MS@CPS Country Best Practices and Lessons Learned

Any pedagogical approach or framework has the potential and often the need to change how we do and approach education and even more instruction. But all general theoretical approaches lead to specific, local implementations, that emerges in context of the individual environments in which education is given and shared. It is informed and transformed by the teachers who are facilitating the education and is influenced and transformed further by social, cultural, and even economic factors. How new approaches are implemented on a local space is reflected by how educators live education within their local universities. This is very much present in the individual, local best practices, reflecting the existing environment of education with all its factors but also reflecting how new educational approaches can be integrated or are integrated. Therefore, the DDCS and CiP approaches, which are at the centre of the MS@CPS education are implemented hand in hand with the local best practices to develop interventions at the local level which adhere to the pedagogy components but are planned and composed by the local instructors, creating their own unique local implementations for a personalized, domain and need specific format.

Throughout the MENA country partners of the MS@CPS we collected best practices that are forming and embedding the MS@CPS pedagogy. The best practices are gathered based on a questionnaire, which were filled within the project teams and in interaction with the departments and the wider university. The perspectives gathered are collected in the following and will be built on in the ongoing implementation of the practical education perspective.

4.1 **Tafila Technical University (TTU) -** Best Practices

4.1.1 Teaching best practices

Teaching Organization: How is teaching organized locally? Is there a centralized organ or board organizing and aligning the lectures in regular cycles? Are lectures assigned to lecturers long term without alignment?

First, the teaching is organized by a committee at the academic department that offers the courses. This committee assigns the courses to instructors based on their research interests and their desire to teach specific courses.

Second, there is a central committee that reviews all the suggested courses schedules for all departments. Then, the directorate of admission and registration distributes the courses to the available classrooms and labs.

Teachers Management: Is there a "train the educators" program or something comparable to ensure the teaching quality? What are the best practices for keeping educators up to date?

Most of the instructors develop themselves through self-study and training. In some cases, some organizations and agencies offer our instructors training courses that focuses on new technologies or practices, especially in engineering. Also, the instructors are funded to participate in local and international conferences.

Educational Methods: Are educational methods and techniques in place or endorsed in the organisation or used by one or more teachers? E.g. flipped classroom, creation and use of Open Educational Resources,

Direct instruction: The instructors prepare the course materials as presentation files, and then they discuss the contents with students during the class time. Some of teachers use the free online services such as google classroom, Microsoft teams, and Thuraya as educational platforms to teach the students.

Differentiate instruction: In some courses, the instructors know their student's capabilities well, so they provide them with experiences and duties. For example, students are given choices for reading or writing through motivating assignments that meet the students' diversity and experiences.

Inquiry-based learning: the instructors pose questions, problems, or scenarios. The students are requested to provide their responses, which are supported with references. This kind of learning can be used effectively in online courses.

Project-based learning: The instructors distribute students into small groups. Each group has 2-4 students who are working together on a practical project or research report, depending on the nature of course.

4.1.2 Project focused education

Project-based Education: Do you deploy different formats to support a project focused education? E.g. paper discussions, application focused seminars, project groups or works, managed internships. What would you recommend to support a deeper project integration?

Yes, we use different formats to support project-based education especially in engineering and applied sciences. The students are asked to conduct small research projects. Then they present their results in a seminar. Also, we highly focus on asking students to prepare a research paper, especially in the advanced courses, in order to give them the opportunity to learn how to collect, analyse, and present the results in a specific topic as a research paper.

Cross-cutting/Cross-domain Education: Do you offer classes or practical sessions that on purpose integrate one or more separate topics to explore their fusion? What type of sessions or events would you recommend to do so?

We propose to integrate the elective courses that focus on the topic of thesis. This integration can provide the students a solid foundation to conduct their research successfully.

Industrial Integration: What do you do to integrate the industry directly or industrial requirements into the lectures? E.g. invited talks, managed internships, job fairs, collaborative workshops, topic focused open-door days like "day of data analysis/IOT", start-up incubators. What would you recommend to strengthen the integration of the industry?

The industry can be integrated into the courses offered in proposed program in many ways:

- **At each institution, an internship program can be launched with our industrial partners. All the requirements, objectives, and practices needed in this program will be agreed to from both industry and institutions to ensure that the students gain a strong experience and knowledge in CPS domain.**
- **We can organize career days in cooperation with the industrial organizations. This can provide the students the most important jobs' qualifications required by industry.**
- **We suggest having specialists from the industry to be part of the discussion committee of master theses in order to take advantage of their expertise.**
- **Working on holding a yearly workshop in cooperation with industry partners. As graduation requirement, all students must participate in these workshops.**

4.1.3 Technology Enhanced Learning

Learning Management Systems (LMS): Do you use and/or recommend solutions to support the management of the learning and teaching operations?

We recommend Blackboard system to help us in managing the teaching process.

Supporting Technologies: Do you successfully use software systems to enhance your teaching/learning? E.g. video platforms, interactive assessment and learning platforms, MOOCs, electronic boards and in-class technologies as enhanced whiteboards? Would you recommend specific solutions?

We use the following technologies that enhance the teaching at the classrooms such as MOOCs (https://www.mooc.org/), open-source learning platforms (Moodle), and in-class technologies (whiteboards and datashows)

4.1.4 Summary Statement

If there are two best practices you could select for an MS@CPS education, what would they be?

We highly recommend the integration between the courses and industrial internships and projects. This would help the students to link what they learn with what the industry really has.

4.2 **Higher Institute of Applied Sciences and Technology of Mateur (ISSATM) Carthage University (CU) -** Best Practices

4.2.1 Teaching best practices

Teaching Organization: How is teaching organized locally? Is there a centralized organ or board organizing and aligning the lectures in regular cycles? Are lectures assigned to lecturers long term without alignment?

At ISSATM (CU), firstly, before starting the semesters, the heads of the departments send to lecturers by email a choice form to fill out. In the form, the assistant professors are invited to put their proposals for the courses. At the beginning of the year the heads of departments and the studies director plan a meeting where they present to the different assistant professors the content of the courses that will be offered according to the students study plan and which respect what has been submitted and accepted by the accreditation committee. They assign the courses to assistant professors based on their research interests and their choices to teach specific courses sent before by email.

Studies director, heads of departments and teachers discuss during the meeting about the assignment of courses and resolve the situation if there is an overlap between teachers' courses proposals. During the meeting, the courses are assigned to the teachers based on their research interests and their desire to teach specific courses. The assignment usually takes into consideration lecturer experiences and research interests. Before each semester, such meeting is planned.

Teachers Management: Is there a "train the educators" program or something comparable to ensure the teaching quality? What are the best practices for keeping educators up to date?

At ISSATM (CU) there are three kinds of training:

- **Educators develop themselves through self-study and training.**
- **Educators can also benefit from training programs as part of projects achieved by the teachers of the establishment, by the team of the career and skills certifications centre in the institute (such support quality projects).**
- **The direction of the institute gives the necessary funds to educators who need training useful for teaching to attend such events.**

Educational Methods: Are educational methods and techniques in place or endorsed in the organisation or used by one or more teachers? E.g. flipped classroom, creation and use of Open Educational Resources,

Most teachers use face to face teaching methods, teachers send to students the courses by email, and during face-to-face sessions, they present and explain them.

We note that during the current crisis, an e-learning platform specific to ISSATM has been developed and has been hosted where teachers download their lessons and there is also a chat space with students. Many lectures also are given using Zoom, Google meet, Google hangout, Visio...

4.2.2 Project focused education

Project-based Education: Do you deploy different formats to support a project focused education? E.g. paper discussions, application focused seminars, project groups or works, managed internships. What would you recommend to support a deeper project integration?

Yes, we use different formats to support project-based education such paper discussions, application focused seminars, project groups, and managed internships mostly - for master and even for licenses.

Cross-cutting/Cross-domain Education: Do you offer classes or practical sessions that on purpose integrate one or more separate topics to explore their fusion? What type of sessions or events would you recommend to do so?

At ISSATM (CU) students have many internships where they apply what they have learned in many courses. We offer also the entrepreneur student pole of Carthage where students choose and work on projects. The domains they choose are different: IT, agriculture, art ... There are also clubs where students work on projects.

The main objective of the Carthage Student Entrepreneur Pole (in french PEEC : Pôle Etudiant Entrepreneur de Carthage https://www.facebook.com/PEECarthage/) is to promote entrepreneurship and innovation among students of the University of Carthage. The Student Entrepreneur Pole of Carthage will provide personalized support and mentoring adapted to the needs of students at the University of Carthage who will benefit from the status of student entrepreneurs.

Industrial Integration: What do you do to integrate the industry directly or industrial requirements into the lectures? E.g. invited talks, managed internships, job fairs, collaborative workshops, topic focused open-door days like “day of data analysis/IOT”, start-up incubators. What would you recommend to strengthen the integration of the industry?

The industry can be integrated into the courses offered in the proposed program in several ways:

- **Internships program can be launched with our industrial partners.**
- **Several teachers are contractual industrial experts according to the needs of the university. They bring industry practices to the university.**
- **We have submitted a quality support project with the support of our industrial partners. As part of the project we will organize industry days (for recruitment, for internships), we will organize hackathons and entrepreneurial competitions in partnership with industries.**

The institute's career centre has already organized hackathons in partnership with industries.

4.2.3 Technology Enhanced Learning

Learning Management Systems (LMS): Do you use and/or recommend solutions to support the management of the learning and teaching operations?

We have a platform for e-learning based on Moodle, we recommend using it for the Master to be implemented.

- **The platform of our own ISSATM (CU) institute.**
- **The platform of the virtual university in Tunisia.**
- **A Microsoft platform.**

Supporting Technologies: Do you successfully use software systems to enhance your teaching/learning? E.g. video platforms, interactive assessment and learning platforms, MOOCs, electronic boards and in-class technologies as enhanced whiteboards? Would you recommend specific solutions?

All the teachers join since the crisis of the pandemic to the use of different technologies in teaching such as Moodle platform, learning platforms, synchronic meetings, MOOCs.

4.2.4 Summary Statement

If there are two best practices you could select for an MS@CPS education, what would they be?

We recommend:

- **A teaching based on IT and entrepreneurial projects and industrial internships.**
- **Many partnerships with national and international industries.**

4.3 **Palestine Technical College (PTC) -** Best Practices

4.3.1 Teaching best practices

Teaching Organization: How is teaching organized locally? Is there a centralized organ or board organizing and aligning the lectures in regular cycles? Are lectures assigned to lecturers long term without alignment?

At PTC, the assignment of lecturers to courses is done at each academic department separately before the start of each semester, based on the experience of the academic staff. It is done in agreement between academic staff and the academic department head in each department. The vice dean for academic either approves this assignment or makes some modifications on it. The quality assurance monitors the teaching process by considering feedbacks from students and academic departments heads.

Teachers Management: Is there a "train the educators" program or something comparable to ensure the teaching quality? What are the best practices for keeping educators up to date?

Yes, there are training workshops and courses held regularly to improve the knowledge and skills needed for teaching and the evaluation of students.

Educational Methods: Are educational methods and techniques in place or endorsed in the organisation or used by one or more teachers? E.g. flipped classroom, creation and use of Open Educational Resources,

Yes, there are many different methods and techniques used in theoretical and practical courses. Expeditionary Learning is applied in project-based courses. In such courses, students apply their gained knowledge to solve problems that they face in their communities. In general, lecturers have the freedom to decide what method fits to their course and they can apply it. However, most lecturers follow the direct instruction approach.

4.3.2 Project focused education

Project-based Education: Do you deploy different formats to support a project focused education? E.g. paper discussions, application focused seminars, project groups or works, managed internships. What would you recommend to support a deeper project integration?

Yes, in certain advanced courses such techniques are used but not in all courses.

Cross-cutting/Cross-domain Education: Do you offer classes or practical sessions that on purpose integrate one or more separate topics to explore their fusion? What type of sessions or events would you recommend to do so?

Such practices are not used at PTC, but it would be desirable to learn them from experienced universities.

Industrial Integration: What do you do to integrate the industry directly or industrial requirements into the lectures? E.g. invited talks, managed internships, job fairs, collaborative workshops, topic focused open-door days like "day of data analysis/IOT", start-up incubators. What would you recommend to strengthen the integration of the industry?

At PTC, integration with industry is done in a few forms but clearly its share should be increased. There are field training courses or sessions at the industry offered in some study programs. Workshops are held with the participation of industry but not within courses. We recommend to work on topics for master theses and graduation projects that solve problems in the industry.
4.3.3 Technology Enhanced Learning
Learning Management Systems (LMS): Do you use and/or recommend solutions to support the management of the learning and teaching operations?
Yes, Google classroom is adopted as LMS. LMS usage becomes more effective after COVID-19 pandemic. Other platforms e.g. Moodle is under consideration.
Supporting Technologies: Do you successfully use software systems to enhance your teaching/learning? E.g. video platforms, interactive assessment and learning platforms, MOOCs, electronic boards and in-class technologies as enhanced whiteboards? Would you recommend specific solutions?
Those staff who are capable of using IT systems can employ software systems but not all academic staff are capable of using IT solutions.
4.3.4 Summary Statement
If there are two best practices you could select for an MS@CPS education, what would they be?
We think project-based education would be suitable for all MS@CPS courses and industry integration would enhance the chances of job finding for the graduates. Therefore, those two practices would be the best for us at PTC.

4.4 **German Jordanian University (GJU)** - Best Practices

4.4.1 Teaching best practices

Teaching Organization: How is teaching organized locally? Is there a centralized organ or board organizing and aligning the lectures in regular cycles? Are lectures assigned to lecturers long term without alignment?

In Jordan, there is no centralized board or body that organizes the lecturing process. However, each university has to abide to the ministry of higher education outcomes for the taught courses for the accredited study programs.

Teachers Management: Is there a "train the educators" program or something comparable to ensure the teaching quality? What are the best practices for keeping educators up to date?

In Jordan, and more specifically at the German Jordanian University, we have a train-the-trainer program where university professors and administrative staff can apply to the program and travel to Germany to receive a training in a specific field. Further, the university often runs several train-the-trainer programs for the faculty members and administrative staff to improve their soft and technical skills.

Educational Methods: Are educational methods and techniques in place or endorsed in the organisation or used by one or more teachers? E.g. flipped classroom, creation and use of Open Educational Resources,

At the German Jordanian University, we had previously a project that aimed at promoting the use of open source educational resources and software in the educational process, which had a positive impact on the faculty members and educational processes.

4.4.2 Project focused education

Project-based Education: Do you deploy different formats to support a project focused education? E.g. paper discussions, application focused seminars, project groups or works, managed internships. What would you recommend to support a deeper project integration?

At GJU, we always ask the students to perform practical projects as part of the course's main activities. Furthermore, in many classes, the students are asked to prepare a paper or write a report related for the course.

Cross-cutting/Cross-domain Education: Do you offer classes or practical sessions that on purpose integrate one or more separate topics to explore their fusion? What type of sessions or events would you recommend to do so?

Many classes have associated practical labs, where the students will have the chance to apply the theoretical knowledge and conduct practical experiments. However, for the classes that do not have labs, the students are asked to perform practical projects as part of the course main activities.

Industrial Integration: What do you do to integrate the industry directly or industrial requirements into the lectures? E.g. invited talks, managed internships, job fairs, collaborative workshops, topic focused open-door days like “day of data analysis/IOT”, start-up incubators. What would you recommend to strengthen the integration of the industry?

Integrating the industry into the teaching curricula is paramount, especially with the recent emerging technologies. To have an effective industry involvement, several activities could be conducted such as:

- **Inviting speakers from the industry.**
- **Conducing projects in partnership with the industry.**
- **Arranging workshops with the industry.**
- **Arranging internships for the students with the industry.**

4.4.3 Technology Enhanced Learning

Learning Management Systems (LMS): Do you use and/or recommend solutions to support the management of the learning and teaching operations?

It is important to have an eLearning and resources management system so students can easily access the educational material and submit the performed reports and projects.

It is important to have a live eLearning conference facility that can be used for online and blended teaching.

Supporting Technologies: Do you successfully use software systems to enhance your teaching/learning? E.g. video platforms, interactive assessment and learning platforms, MOOCs, electronic boards and in-class technologies as enhanced whiteboards? Would you recommend specific solutions?

I do recommend incorporating all the above supportive materials especially videos and MOOCSs.

4.4.4 Summary Statement

If there are two best practices you could select for an MS@CPS education, what would they be?

- **Heavily industrial engagement.**
- **Perform practical projects.**

4.5 **University of Sfax (USF) -** Best Practices

4.5.1 Teaching best practices

Teaching Organization: How is teaching organized locally? Is there a centralized organ or board organizing and aligning the lectures in regular cycles? Are lectures assigned to lecturers long term without alignment?

At USF, we plan a meeting at the beginning of the year where the head of the departments and the responsible of the masters present to the different lecturers and professors the content of the courses that will be are offered according to the students study plan and which respect what has been submitted and accepted by the accreditation committee which contains full professors that study the content and the scope and the relevance of the study program.

During the meeting, the courses are assigned to the teachers based on their research interests and their desire to teach specific courses. The assignment usually takes into consideration lecturers experience and also their position (for research master, full professors, associate professors are privileged). The semester timetable and also all the year's timetable is discussed in order to find a balance between the two semesters.

Teachers Management: Is there a "train the educators" program or something comparable to ensure the teaching quality? What are the best practices for keeping educators up to date?

There is no fixed program to train the educators but if someone asks for a training since he (she) needs it for teaching, the direction of the institute give him the necessary funds to attend such activities. The responsible of the master and the head of department follow the advancement of the courses and ensure that educators follow the program and are up to date. In general, there are some pedagogical meetings during the year to ensure this.

Educational Methods: Are educational methods and techniques in place or endorsed in the organisation or used by one or more teachers? E.g. flipped classroom, creation and use of Open Educational Resources,

Most teachers use traditional teaching methods, they prepare their courses in PowerPoint presentations and the presentations are sent to the students and explained during the course. We have a platform for e-learning but not all the teachers use it. But we think in the future all the e-learning techniques will be used.

It should be noted that during the current crisis many lectures are given using the platform Moodle and also many courses are given using Zoom or google meet.

4.5.2 Project focused education

Project-based Education: Do you deploy different formats to support a project focused education? E.g. paper discussions, application focused seminars, project groups or works, managed internships. What would you recommend to support a deeper project integration?

Yes, we support project focused education, essentially for master courses, such as paper discussions, development of projects which are followed and evaluated by the teachers, application focused seminars, project groups or works and managed internships

Cross-cutting/Cross-domain Education: Do you offer classes or practical sessions that on purpose integrate one or more separate topics to explore their fusion? What type of sessions or events would you recommend to do so?
The students have many mandatory internships, where they apply what they have learned in many lectures.
Industrial Integration: What do you do to integrate the industry directly or industrial requirements into the lectures? E.g. invited talks, managed internships, job fairs, collaborative workshops, topic focused open-door days like “day of data analysis/IOT”, start-up incubators. What would you recommend to strengthen the integration of the industry?
Many of our teachers are industrial experts, recruited by the ministry as a contractual (each year) according to the need of the university. This is important to bring the know-how of practitioners and industry into the university. Moreover, we usually invite speakers from industry and have internship programs and organize each year open days and job fairs where we invite many industrials to discuss with them and integrate the students into the industry.

4.5.3 Technology Enhanced Learning

Learning Management Systems (LMS): Do you use and/or recommend solutions to support the management of the learning and teaching operations?
We have a platform for e-learning based on Moodle. We recommend using it for the master to be implemented.
Supporting Technologies: Do you successfully use software systems to enhance your teaching/learning? E.g. video platforms, interactive assessment and learning platforms, MOOCs, electronic boards and in-class technologies as enhanced whiteboards? Would you recommend specific solutions?
Since this crisis, all the teachers adhered to the use of different technologies to aid in teaching such as video platforms, interactive assessment, and learning platforms.

4.5.4 Summary Statement

If there are two best practices you could select for an MS@CPS education, what would they be?
We would recommend project based teaching and industrial internships.

4.6 **Al-Quds University (AQU)** - Best Practices

4.6.1 Teaching best practices

Teaching Organization: How is teaching organized locally? Is there a centralized organ or board organizing and aligning the lectures in regular cycles? Are lectures assigned to lecturers long term without alignment?

At AQU courses are offered according to the students' study plan that is usually prepared at the time of accreditation, with minor changes from time to time. Lecturers are assigned during meetings delegated to discuss the semester timetable. The assignment usually takes into consideration lecturers experience and their preferences as well as semester load conditions to each lecturer. Usual load for each lecturer is 12 credit hours. He/she can take up to 15 maximum.

Teachers Management: Is there a "train the educators" program or something comparable to ensure the teaching quality? What are the best practices for keeping educators up to date?

From time to time lecturers are offered training workshops on pedagogical and research issues. These are usually offered by different projects and not periodical. There is no fixed program for such activities. Currently there is no formal policy to ensure that educators are up to date. The University is currently working on such a policy.

Educational Methods: Are educational methods and techniques in place or endorsed in the organisation or used by one or more teachers? E.g. flipped classroom, creation and use of Open Educational Resources,

Most teachers use traditional teaching methods, that is face to face teaching. In recent years some lecturers moved into using new methods such as flipped classroom and using e-resources in classrooms. AQU has a learning management platform based on Moodle called eclass. Each course is assigned an eclass that can be used by lecturers. Few training sessions are given on the use of eclass. It has been used extensively by technology-oriented lecturers but not the majority uses it.

It should be noted that during the current crisis all lectures are given using the eclass and lectures are given using Zoom.

4.6.2 Project focused education

Project-based Education: Do you deploy different formats to support a project focused education? E.g. paper discussions, application focused seminars, project groups or works, managed internships. What would you recommend to support a deeper project integration?

Some programs use project focused education, in particular at the Faculty of Education. Managed internship is used at the dual studies program, some IT and Engineering programs.

To support deeper project integration there is a need to establish an organised structure and policies to support the project implementation. Projects will be monitored and proposed by a committee from the faculty members and members from the private sector. The projects will be followed in a regular period during the different project phases. Different milestones will be set at the beginning of the project and progress reports are produces at these points.

Cross-cutting/Cross-domain Education: Do you offer classes or practical sessions that on purpose integrate one or more separate topics to explore their fusion? What type of sessions or events would you recommend to do so?
The university offers capstone courses for the different departments in which students carry out interdisciplinary projects that can integrate one or more topics. We believe this is effective to prepare students for the marketplace and requires different training sessions.
Industrial Integration: What do you do to integrate the industry directly or industrial requirements into the lectures? E.g. invited talks, managed internships, job fairs, collaborative workshops, topic focused open-door days like “day of data analysis/IOT”, start-up incubators. What would you recommend to strengthen the integration of the industry?
This is different from department to department, usually we invite speakers from the industry and we have internship programs, the most successful program is the dual studies program where students spend half of the semester at the university and the rest in the industry. Evaluation of the students is done by both parties.

4.6.3 Technology Enhanced Learning

Learning Management Systems (LMS): Do you use and/or recommend solutions to support the management of the learning and teaching operations?
We have a learning management system based on Moodle, that our IT team customised to the University in use. We do recommend using it for the master to be implemented.
Supporting Technologies: Do you successfully use software systems to enhance your teaching/learning? E.g. video platforms, interactive assessment and learning platforms, MOOCs, electronic boards and in-class technologies as enhanced whiteboards? Would you recommend specific solutions?
We use the eclass that has different systems to enhance teaching. We use electronic boards and different technologies to aid in teaching.

4.6.4 Summary Statement

If there are two best practices you could select for an MS@CPS education, what would they be?
We would recommend project-based teaching as well industrial internships.

4.7 Questionnaire Summary and Analysis: Differences and Communalities of Local Education

4.7.1 A Text Extraction Based Analysis of the Response's Concepts and Differences

The questionnaires revealed local difference but indeed majorly communalities towards the goals and expected common grounds of the implementation of the MS@CPS pedagogy, as gathered in section 3. Throughout all questionnaires, university majorly shared their strong support for practical extensions to the classes, a close contact to the industry, together with active involvement and an exchange on industrial, future or job driven requirements. Majorly, a classic teacher-to-student transmission of knowledge is applied, through monolithic one-sided teaching. This is already now extended by practical spaces and practical formats, in which students and teachers interact freely and problem focuses. The shared interest is given to extend the practical phases of the studies, which is a valuable application field for the MS@CPS pedagogy, to which the partners are committed to.

Differences are majorly shown in how much practical teaching is occurring within the existing study programs in which the MS@CPS partner instructors are currently involved in. Furthermore, it differs among partners how strictly and how institutionalized the planning and distribution of teaching is organized. Instructors have a specific strictly regulated level of academic employment, e.g. assistant professor, while others have a range of employment levels for teaching positions or do not report on specifics. One partner specifically attracts and employs members of the industry to deliver classes in a way that they are stronger relevant for the changing requirements of the industry. This supports an up-to-date education, as well as fosters a culture of industry/academia exchange.

To gain an additional angle on the contents of the questionnaire, a limited analysis was done on the unique vocabulary and entities, that are characteristic for the partner responses. A text mining workflow was used, entailing tokenization, stop-word removal and stemming (snowball-based stemmer for the English language), utilizing for the process the works of Zenkert et al. (Zenkert et al. 2018[16]). Utilizing the text mining process, the TF-IDF was applied. TF-IDF[17] stands for Term Frequency-Inverse Document Frequency and is a measure, that is rating how unique words extracted from one document are against words extracted from other documents. It rates highly words which are very representative for a specific document, in terms of use of vocabulary and language and in terms of special entities which may represent domain specific technical term.

Utilizing the text extraction process and the TF-IDF measure, a top five of unique terms or vocabulary were extracted from the responses, considering the full responses (response set) for a single partner as one document. This way we considered six documents. The resulting terms are rated and sorted by the TF-IDF measure and can be seen in ***Table 2*** below. The names of the universities were not counted and therefore filtered from the results, as well as closely related terms as "German" for GJU. For all terms in the results that were stemmed to a shorter form, like "assist", it was checked how the words were used. In case of a unique use in a response set the word were completed, like "assistant", in case of a varied use, the main use was indicated in rectangular brackets, like "instruct[tor]". The context of the use of a term is given in round brackets. For some terms, the rating was the same and they are shown with a slash separation.

It has to be considered for the evaluation that the sample size overall and per university is insufficient to overcome the impact of the individual use of language. As such this analysis is insufficient in its

[16] Zenkert, J., Weber, C., Klahold, A., Fathi, M., & Hahn, K. (2018). Knowledge-based Production Documentation Analysis: An Integrated Text Mining Architecture. 2018 IEEE 61st International Midwest Symposium on Circuits and Systems (MWSCAS), 717–720. https://doi.org/10.1109/MWSCAS.2018.8623836

[17] Manning, C. D., Raghavan, P., & Schütze, H. (2008). Introduction to Information Retrieval. Cambridge University Press.

extent and validity. However, it completes the picture gained from the questionnaires and from the jointly phrased pedagogy and its potential for a local level applicability.

Table 2: A fusion of the top five characteristic words per partner response.

AQU	CU	GJU	PTC	TTU	USF
eclass	entrepreneur	perform (practical projects)	academic (staff/department)	instruc[tor]	full (professor)
timetable	assistant (professor)	administrative (staff)	staff (academic)	provide (students with qualification / foundation)	follow
policy	email	arranging (workshops/internships)	capable (using IT)	cooperation (with industry)	teacher
dual studies	pole	elearning	held	Distribute / help / suggest	present[ation]
load (work) / period	teacher	trainer	LMS / solve	require (qualification, graduation)	responsible / timetable

The top five used, unique vocabulary in ***Table 2***, backs the general observations, gathered in the paragraphs above, as well as special observations as e.g. the highlighting of the regulated level of academic employment. Still, more unique considerations can be extracted, like the name of eLearning solutions as eclass and LMS in general, and the implementation of unique study forms, as dual studies, or the Pole initiative. Another unique focus can be extracted in the vision of practical studies as entrepreneurship, arranging practical formats as internship and perform practical projects indicate. This was expected based on explicit questions towards practical formats but the unique focus throughout also unrelated answers, for some partners, show that a strong practical focus is already an ongoing consideration within the education.

Looking deeper into the specific answers and comparing the answers per partner, shared trends and differences are becoming visible, which are summarised in the next sections.

4.7.2 Summary: Teaching best practices

Teaching Organization is managed with a trend towards a superordinate level management rather than on a team level. Constructs range from explicit committees to department level organisation (top-down teacher/class assignment and bottom-up course proposals), towards peer agreements on how to fulfil needed courses. The announcement of master study coordinators per studies is an option.

Teacher Management (and Training) is handled very diverse but has the communality that no training is obligatory at the universities. Self-studying is the main and foremost followed path to an update of education. This can be accompanied by centralized offers of training within the universities. If a specialized training is needed then, in most universities, funds are available for external training, to which

educators can apply. A unique approach is the best practice of deploying study program managers, who are keeping an overview over the skills of the teachers per program and can recommend training in case of missing knowledge. Another unique approach for training is the utilization of a teacher exchange program with partner universities in Germany, as well as having an active culture for endorsing the visiting of conferences for up-to-date knowledge.

For Educational Methods, the dominant method for all universities is direct instruction in face to face meetings, which are extended by additional methods and the use of technology. To various degrees flipped classroom approaches are implemented. There are two main ways of implementation – the posing of questions and problems, which are then explored by students and the assignment of projects which are interactively solved by groups of students. Both are supported by available teacher. An emphasis lies for some partners on utilizing the close contact to the students to facilitate a more constructivistic approach for teaching, connecting to their previous experiences. Integrated into the class-room experiences are e-learning and video conferencing solutions which support self-directed learning and long-distance learning as an extension of existing methods. Open Educational Resources (OER), are retrieving traction as universities are starting to introduce them for the different methods of instruction. One university profited here from an OER promotion project. The dominant solution for e-learning is the open source platform moodle which can be deployed as an LMS and e-learning solution. Under the influence of the Covid-19 pandemic, all universities deployed online extensions for their courses and started to teach online through video conferencing solutions. To what extend the courses changed on an instructional level, is not part of the questionnaire.

4.7.3 Summary: Project focused education

Project-based Education can be delivered with different types of interventions, supported with different concepts of instruction. All universities use a variety of formats to facilitate the experience of a project in parts or as a whole. Fundamental, applied formats are paper discussions, application focused seminars, project groups and managed internships. Formats are applied continuously to a class or are planned as interventions as practical phases in theoretical or overall mixed courses. A major factor in line with the MS@CPS pedagogy concept is the management of internships to integrate practical phases in the studies, as well as integrating companies or lessons learned from the practical space. A unique extension for it is the planning of industry relevant certification along classes to focus on areas which are proven to be industrial relevant, as well as bridging into the later job market.

Cross-cutting/Cross-domain Education instruction is an important tool towards an integrated education. But it is also especially a reflection of the specific requirements of CPS education, which, in many areas, requires the fusion of disciplines for fostering a cross-disciplinary understanding. Across all universities, formats are implemented which facilitate interdisciplinary works. However, in most cases the formats are not accompanied by an explicit instructional concept. In general project-based instructions are used within the local courses, which often implicitly integrate multiple domains. Furthermore, special initiatives, like the Pole initiative, which supports students towards entrepreneurship in a cross-cutting mentoring program. In terms of explicit initiatives, the implementation of cornerstone courses is a major step towards an integrated, cross-domain instruction. Similarly, master thesis works, as one implementation of cornerstone courses, can provide such an experience for the students. However, the instructional support has to be facilitated by the individual instructors, in line with the specific needs of the given student and topic. One highlighted approach can be that especially elective courses are taught in a way that implements a long term vision that prepares students early to use their gained skill-sets for a topic- and method-wise fusion of disciplines in the later thesis works.

Industrial Integration is a vital factor for the integration of state-of-the-industry topics and solutions, as well as for the strengthening of the market relevance of the offered studies and courses. Universities already today implement initiatives that facilitate the industry integration into the study programs.

One method is to organise industrial days as an open floor for exchange between industry and university. A part of the universities is already today hiring industrial experts as instructors to give lectures as part of the individual curricula. One model is here to directly employ such experts by the state and managed by the faculties, which can be an employment model for more universities. Dual studies are another direct collaboration where both stakeholders are present in the education and evaluation, facilitating exchange and the industrial relevance through involved students and instructors. More class-oriented initiatives are field trips or teaching sessions in the industrial space, as well as inviting industrial speakers into the individual lectures. Initiatives are either coordinated by the teams of instructors or through the career office of the university. Recommendations are to deepen the exchange and give industrial expertise a stronger role in the curriculum and especially in the master thesis works, and to contextualize the studies and ensure a continuous industrial relevance. This is especially valuable for CPS studies, as relevant industries are employing experts with a high level of education, which can support students on a university level of education. Such initiatives can be further consolidated and coordinated with an explicit internship program and project collaboration program, that equally involves industrial and university participation.

4.7.4 Summary: Technology Enhanced Learning

Learning Management Systems (LMS) are supporting the general stream of learning with electronic support tools. Depending on the specific implementation this can explicitly integrate the management of the student's progress with a partial HR perspective. LMS are used across all universities with varying levels of integration into the organisational and teaching oriented presses. The mainly used solutions are moodle, blackboard and google classroom. Selected universities implement customizations of such platforms, especially moodle, or are connected to national systems as the virtual university in Tunesia. All universities use and recommend the use of LMS systems. The used solutions indicate that the implementation and integration is foremost motivated by availability and extendibility.

Electronic or digital solutions can be used as **Supporting Technologies** to scaffold or support teaching and learning activities. Solutions are available for nearly all aspects of teaching and learning and can be utilized to support instructional concepts on all levels, ranging from national/international to complete individual compositions. Instructors are using and recommending a wide array of electronic tools and digital solutions, which were covered throughout the questionnaire till the supporting technology section. However specific tools are in use beyond that. Specifically, MOOCS and electronic white boards, as well as projectors are incorporated into the learning and teaching. However, the selection and utilization are in the hands of the instructor, as far as tools are available. A deeper understanding of a digital method and theory of instruction could close the gaps between traditional instruction and new technologies for a technology enhanced education.

4.7.5 Summary: Summary Statements

A major factor for the introduction of any new method in the field of education, and specifically instruction, is the readiness of the teachers and the local environment. The feedback, gathered from the questionnaire, showcases the already existing endorsement of all partners to apply a pedagogy, focused on gaining and integrating practical experiences within practical phases within the flow of the lectures. Furthermore, all partners are committed to further close the gap between the education of today and the industrial needs of tomorrow for a technology and research heavy application as CPS, using the MS@CPS pedagogy vision. This was shown throughout the questionnaires and specifically underlined with the collected final statements per university. The specific implementation of the practical methods within the pedagogy is individual and local in its nature but the frame and design of the specific intervention, fits to the project- and practice-based vision of MS@CPS and as such adheres to the DDCS and CiP methods and motivation.

5 MS@CPS Whitepaper: Best Practices and Commitments for MS@CPS Education

The MS@CPS is intended to be a way mark proposal for CPS education across the globe. To teach CPS is to live and teach the intersection of the cyber and the physical, of the composing domains and last but not least, intersect different research and social cultures. To envision a shared CPS education with the highest standards, the educators of the MS@CPS are committing to the following MS@CPS best practices:

- **Educational Standards:** To **utilize and share common standards for a comparability of education**, as the Revised Blooms Taxonomy[18] to define, structure, occasionally rethink and sustain teaching through its envisioned intellectual outputs and their implementation through student-focused teaching and learning formats.

- **Gender Equality:** To **continuously reflect how to reach and upkeep a gender balance among students and educators** and **advocate and ensure a fair and equal treatment** of students and personnel with highest respect to the individual needs and personal integrity. Equality does not stop at the gates of higher education but shall transition equally into the markets, carried by the graduates but also supported by the educators by involving industries within and beyond the curriculum and the vision for CPS education.

- **Future Oriented Teaching:** To **continuously strafe to modernize and extend the offered MS@CPS education**, based on the scientific and industrial development and for a sustainable and future-oriented MS@CPS education. This especially encompasses a future commitment to continuously move towards a more mobile, technology enhanced teaching, supporting, and extending existing and future teaching. Future oriented teaching involves the adequate teaching methods to accompany and enable new technologies, which in turn enable novel and improved pathways of learning. At the heart of is change but the long-term motivation is to have a global, border independent, mobile, transnational way of teaching and learning, offering curricula across borders and across multiple universities for shared and recognized educational degrees.

- **Open Education:** To **adhere to the principles of open education and open science** and pass on those principles to future generations to create and sustain an open and inclusive research community, following the Plan S where it is possible[19]. Education is open if it is accessible not only content-wise but also as an institution, independent of socio-economic boundaries. MS@CPS education will look out for ways to break overcome limitations towards the ability to join the program, following the UN's 17 sustainable development goals (SDGs)[20].

- **Linking Industries:** To **continuously reflect how to ensure and extend the integration between industry and teaching process of MS@CPS**. This integration keeps the community (students and educators) in touch with recent developments in the technologies and practices. The industrial partnership is at the start and the finalization of each cycle of

[18]Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. Theory Into Practice, 41(4), 212–218. https://doi.org/10.1207/s15430421tip4104_2

[19]"Plan S" and "cOAlition S" – Accelerating the transition to full and immediate Open Access to scientific publications. (2018). https://www.coalition-s.org/

[20]United Nations. (2015). About the Sustainable Development Goals. United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

MS@CPS curricula development and is at the heart of a sustainable, market focused CPS education based on a continuous industry and higher education exchange. MS@CPS education recognizes the leadership of industrial research in respective domains of CPS application and strives to jointly develop and integrate new research and lessons learned in industry and higher education into the curriculum.

- **Industrial/HE collaborative education practices:** To **enable joint formats and shared space of education, including new teaching formats to enable a novel, practice-oriented education** (hackathons, simulated start-up incubators, start-up accelerators). MS@CPS education commits to organize studies in a way that students explore the labour market throughout their studies, beyond educational practices by endorsing dual studies and entrepreneurial activities from the very beginning of education, supported and integrated into the novel formats of educational-industrial study.

- **Think International:** To **adhere to the principle of program internationalization and learning mobility** to enhance the collaborative learning within the MS@CPS program that is developed by a group of institutions from different geographic areas with experiences in international education and mobility, in line with the principles of the Erasmus charter for higher education[21].

- **Education and supervision beyond borders**: **MS@CPS is an international community, crossing borders and so does its education**. Students join projects to practice their skills, but they are not alone. We thrive to create formats to have students from different partner countries join and collaborate on projects in their masters. Where skills are harnessed, students profit from guidance and supervision and we provide it together. Wherever possible and wherever needed, students are co-supervised by faculty members from different MS@CPS partner universities, educating and connecting beyond country borders.

[21]Smith, J. (2016). Erasmus Charter for Higher Education. Erasmus+ - European Commission. https://ec.europa.eu/programmes/erasmus-plus/resources/documents/applicants/higher-education-charter_en