Theoretical State-of-Art Report

D2.1

Version	Date	Author	Institution	Status	Change Description
0.1	22/04/18	Filomeno Martina	Cranfield University	Draft	First draft
1.0	16/07/2018	Filomeno Martina	Cranfield University	Final	

Author Institution Sign-Off 1	**Signature**	**Date**
Filomeno Martina Cranfield University		16/07/2018
Author Institution Sign-Off 2	**Signature**	**Date**
Approval Institution Sign-Off	**Signature**	**Date**
Filomeno Martina Cranfield University		16/07/2018

Co-funded by the Erasmus+ Programme of the European Union

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Executive Summary

An economy based on the knowledge requires a workforce capable to address challenges worldwide-based rather than locally-based, demanding co-operation between companies, governments, education institutions and society (Fornea & Van Laere, 2015).

Additive Manufacturing is an umbrella designation comprising different processes for a set of materials (metals, polymers, ceramics and others) applied in an array of fields (medical, dental, automotive, electronics, consumer goods, among others), shaping new approaches and innovations to manufacturing and, consequently, to products (Fornea & Van Laere, 2015).

The way higher education institutions organise their instruction, research structures and services, nowadays require sophisticated innovation of approaches to organise knowledge and to approach teaching and learning in order face the challenges mentioned.

Under the organisation of knowledge strand, principles such as disciplinarity, multidisciplinarity, interdisciplinarity and transdisciplinarity will be under discussion. Under the approaches to teaching and learning strand, principles endorsed across Europe in higher education, such as student-centred learning and self-directed learning will be exposed.

The report shows the student-centred learning and self-directed learning are compatible, sharing some principles that already widely implemented in Europe, such as the learning outcomes and problem-based learning methods to deliver education programmes. Additionally, student is perceived as a key stakeholder entitled to take responsibility over choices and for governance purposes.

The statements underpinned to each approach (SCL and SDL) seem possible to be applied to the Metal AM MSc, either at macro and micro levels.

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1 Introduction

An economy based on the knowledge requires a workforce capable to address challenges worldwide-based rather than locally-based, demanding co-operation between companies, governments, education institutions and society (Fornea & Van Laere, 2015).

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This report aims to discuss which principles are going to be applied to the rationale and skeleton underpinning the design of the new Metal AM MSc structure, from the points of view of organisation of knowledge, teaching, and learning.

Finally, the last section explains how the principles selected will be mirrored in the new Metal AM MSc.

2 Aims and Objectives

The aim of this document is to investigate the state-of-the-art on educational principles and methodological approaches to:

- Develop the rationale and skeleton underpinning the design of the new Metal AM MSc structure;
- Promote a common ground perspective on the topics;
- Deliver an educational offer with teaching, learning and assessment strategies adapted to students' needs;

3 Current State of Principles used in Higher Education

The Bologna Process results from an intergovernmental cooperation of 48 European countries in higher education field to, in a nutshell, strengthen quality assurance, ease the recognition of qualifications and periods of study and introduce cycles of studies (bachelor, master and doctorate levels) and modernise education. (European Commission, 2018)

This ambitious shift of paradigm in higher education has driven enormous changes when shaping education programmes, by promoting learner-centred strategies and including tools to enhance flexibility (European Higher Education Area, 2018). Some concepts and strategies deemed fundamental for higher education are explored in this section.

3.1 Conceptualisation: Discipline, Multidisciplinarity, Transdisciplinary and Interdisciplinarity

Epistemology is a philosophical branch that studies the origin, extent and source of knowledge. (Bernstein, 2014). Epistemology has influence in the way the curriculum is planned, particularly in the nature of the subjects contributing to the curriculum, in the teaching and learning strategies employed and how knowledge is organised.

Under the organisation of knowledge strand, principles such as disciplinarity, multidisciplinarity, interdisciplinarity and transdisciplinarity, which are briefly discussed in this report.

3.1.1. Disciplinarity

According to Dogan (2001) discipline refers to organisation and production of knowledge. The term “discipline” originally a term from nineteenth century and is understood as a branch of instruction for the transmission of knowledge and as a convenient mapping of academic administration. Along the years, the knowledge has become, increasingly, more fragmented and specialised. Engineering is an example of applied sciences (i.e. in contrast with pure sciences, such as math or chemistry) that has become more specialised, as new areas of knowledge are being explored (i.e. nanotechnology engineer).

3.1.2 Multidisciplinarity

An approach based on a group made of items with different experiences, qualification and/or skills. However, these are seen in a complementary way, and together they contribute to achieving set aims and objectives, in a better way than if the items acted individually. In the context of teaching, a multidisciplinary course is one taught by a team, in which a single topic, or subject, is analysed using tools and approached of two or more disciplines.

The benefit for the student is that s/he can analyse a single subject using point of views coming from different fields and ultimately new conclusions, otherwise impossible, are drawn. (Dillon, 2001)

3.1.3. Interdisciplinarity

In this approach methods developed in one discipline are applied to another. Research overspills from a discipline to the other, crossing the boundary between the two (or more). Often it is based on the combination of two or more disciplines within one single activity, and it results in the creation of novelty by drawing across disciplinary boundaries. It has proven of fundamental importance when new societal needs arise, for instance a new profession.

Within education, pedagogy and andragogy it refers to the application of methods drawn from several disciplines; it involves teachers, students and researchers with a shared goal or a common task, with the shared application of different academic approaches, professions, techniques and technologies. It is definitely recommended when tackling a complex problem that can be solved only if two or more disciplines are interrogated together and symbiotically. When applied to the design of educational programmes commonly they integrate several disciplines and focused in solving complex problems stemming from a theme, problem, question or idea. Collaborative work is promoted when delivering education through assignments, group work projects leveraging practices of critical thinking and praxis-based learning. (Klein & Newell, 1997)

3.1.4 Transdisciplinarity

A holistic approach to research or teaching whose strategy is not limited to one discipline, and it can be applied to problems that indeed do not belong to one discipline only. Pioneered in medicine (f.i. the application of informatics to genetics or biology), it can also apply to methods

or concepts that were generated in a specific field but are eventually applied to others. It facilitates a systemic approach to problem solving, because it considers inputs and tools that belong to different types of stakeholders.

This approach is about planning of future curricula in the context of emerging ideas, being science considered a source of innovation covering his vision for transdisciplinarity in the university of the future, integrating education, research and service. (Bernstein, 2014; Bernstein, 2015).

Differences between the three

According to Nicolescu (2011), substantial differences exists between multidisciplinarity, interdisciplinarity and transdisciplinarity.

Multidisciplinarity involves working with several disciplines at the same time, separately. On the other hand, interdisciplinarity promotes jointly collaboration towards one goal, blurring boundaries amongst them, integrating and synthetizing information across disciplines. Conversely, the objective of both multidisciplinarity and interdisciplinarity will always remain within their research remit.

Transdisciplinarity's main objective is the understanding of the current world, and this is pursued beyond disciplinary research's framework.

3.2 Approaches in Higher Education: Student Centred Learning, Self-Direct Learning

The European Higher Education Area is becoming increasingly more open to non-traditional students, more mature and experienced engaged in lifelong learning, which are able to design learning strategies that are meaningful for them (Iversen, A., et al, 2015). On the other hand, higher education institutions feel the responsibility to prepare the newer generation to cope with lifelong learning. So, higher education institutions are embracing Student-Centred Learning (SCL) and Self-Direct Learning (SDL) environments, explained in the following paragraphs.

Definition

According to the "Student-Centred Learning - Toolkit for Students, Staff and Higher Education Institutions, European Students' Union and Education International" (2010) published by the European Students' Union (ESU) and Education International (EI), Student Centred Learning (SCL) is a learning approach based on constructivist theories of learning. It is part of the organisational culture and is characterised by placing the student centrally, as an active participant to his/her own learning. Innovative methods with a strong focus on communication with teachers and other learners are needed. In such way, the development of transferrable skills like problem-solving, critical thinking and reflective thinking is promoted and facilitated.

The concept

As explained in 2009 in the Leuven/Louvain-la-Neuve Ministerial Communiqué, the importance of the teaching mission of higher education institutions must be reasserted. In this respect, also curricula must be constantly monitored, assessed, and reformed if required. Each learner must be empowered, new approaches to teaching and learning must be developed, and support and guidance structures must be put in place. Consequently, curricula are far from frozen, and educational paths which are flexible and tailored to the individual needs must be pursued. The importance of this approach is underlined by its high consideration within the broad European Standards and Guidelines for quality assurance (European Students Union, 2015)

The shift in culture

SCL is not a simple methodology but indeed requires a substantial shift in the organisational culture. While it draws on existing processes such as the implementation of the Bologna tools, the various recognition procedures, and ECTS calculated based upon the learning outcomes, it also suffers from the inadequacy of the existing quality assurance mechanisms. For instance, in higher education greater emphasis is put on academic research, rather than teaching excellence. The UK is tacking this issue by implementing the Teaching Excellence Framework, alongside the already existing Research Excellence Framework. Consequently, a shift in the focus from institutional leadership based on research output only, to both research and teaching/learning will be promoted at management level. A larger investment in development of teaching skills and new teaching methods is foreseen. Students will be

expected to take a more central role too, by taking advantage of collaborative learning methods, as well as by challenging established teaching methods.

A shared understanding: the nine fundamental principles

Appreciating the need for a common definition of SCL, discussions with teachers and students occurred during a Conference launching the T4SCL project (Bucharest, May 2010) Nine general principles were thus generated (European Students union, 2010; European Students Union, 2015):

1. **SCL requires an on-going reflexive process**

   The statement means that higher education institutions need to put in place mechanisms to continuously discuss and enhance practices of teaching and learning and ensure the learning outcomes are attained.

2. **SCL does not have a "one-size-fits-all" solution**

   The statement is grass rooted in the idea that all higher education institutions are different as well as its context and students and stakeholders and as such, the learning and teaching strategies should be conceived for fitting the ones involved, especially students and teachers. Flexible curricula and individual learning paths should be encouraged, not only in terms of content (f.i. with a selection of elective modules), but also in choosing the teacher and class times, if possible. In certain universities students can even take extra credits without paying extra fees.

   An example of good practice is the Polytechnic University of Valencia, where the faculty board defines a curriculum based on subjects and materials; subsequently the various departments decide which courses are aligned with the specific curriculum. Then it is taken to the board of the university; if approved, it goes to the national council and then to the national quality agency, from where it come back with a report, and hopefully an approval. In Tallinn University, students can choose freely at least 48 ECTS, which can be taken from totally different courses or institutes.

3. **Students have different learning styles**

A consistent and wide range of possibilities should be available for learning according to what each student feels most comfortable with (e.g.: delivering assignments, have practical experience, expository classes, memorising and recalling information, etc.).

4. Students have different needs and interests

Support services for students must be available to make sure academic success is achieved, appropriate assistance is received and wellness is promoted.

5. Choice is central to effective learning in SCL

Variety of different subjects and courses for students to pick from and enrol themselves, according to their personal interests.

Please do also refer to statement 2 - SCL does not have a "one-size-fits-all" solution.

6. Students have different experiences and background knowledge

Students' experience and previous knowledge must be balanced when designing courses. Therefore, contents, teaching and learning tools should be adapted and should be given the possibility for them to share their perspectives.

7. Students should have control over their learning

Students should be involved in the design process of courses and evaluation in order to ensure they are engaged throughout the education programme, being an active part of the decision-making process, which includes also the development of curricula. Means can be student organisations, parliaments, boards, senates, or other bodies within the universities.

Good practice:

An example of good practice comes from a university in Portugal, where the rector meets with students' representatives, a professor, and an assistant for social services, once a month. (European Students union, 2010; European Students Union, 2015)

8. SCL is about enabling not telling

This statement reproduces raises the awareness on the shift of paradigm that should be promoted in higher education, which involves give the student an active role, the chance to master skills instead of reproduce knowledge and practices, without applying critical thinking.

9. **Learning needs cooperation between students and staff**
   Cooperation amongst teaching staff and students should be promoted and joint solutions should be encountered.

3.2.1 Self-directed learning

Definition

In a world moving at an ever-increasing pace, considering learning as a mere one-off transfer of knowledge is wrong. Concepts and ideas become obsolete quickly, therefore it is very important to be able to understand what gaps form in one's knowledge, during the entire life, and decide how to best fill them.

The self-directed learning (SDL) approach aims at doing exactly this; it is the process "in which individuals take the initiative with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying resources for learning, choosing and implementing learning strategies and evaluating learning outcomes" (Knowles, 1975).

There is a growing body of evidence which shows that when people take their own initiative in learning end up learning more and better than the others. Moreover, SDL is aligned with our natural psychological development, in that it promotes an increasing responsibility over one's career and life in general. Finally, if SCL is considered, it is obvious how there is more and more emphasis on the learner being at the centre of the teaching/learning experience and therefore s/he needs to show a higher degree of initiative. Of course, teacher also play a vital role in promoting the acquisition of the skills needed for SDL.

An interesting and remarkable example of SDL lies in its application to the medical sector. It is unthinkable that in the medical education everything can be taught: there is an exponential growth in the body of knowledge, which cannot be dealt with by simply adding more "chapters" to a curriculum. Moreover, the issue of the obsolesce of notions is particularly felt in the health education.

Consequently, the capacity to analyse problems, and identify what the gaps in knowledge to address them are, knowing where to scout for information, how to assess it, and ultimately be aware of one's limitations are skills needed throughout the entire life.

Principles and necessary implications (Knowles, 1975)

Some principles are underpinned to self-direct learning, which are explored below and listed possible strategies to accomplish them.

1. **Self-initiative by the learner / Student motivation**

Self-initiative/ student motivation relies on the either engagement or lack of engagement of the student to complete tasks.

Strategies: deliver outcome-based education; enable choice in task assignment; design assignments which are challenging but at the same time achievable.

2. **Self-diagnosis of learning needs / Locus of control**

Self-diagnosis of learning needs/ locus of control is defined by the students' ability to assess the knowledge and skills mastered and learning gaps. Self-diagnosis is intimately linked with the concept "locus of control", which is the students' perceptions over their own success and failures. Locus of control might be based in either internal (effort, ability, motivation, strengths) or external factors (chance, luck, others' actions). Students who are aware of their own strengths and weaknesses (internal factors) are more likely to be able to improve learning results. Rotter (1966, in Miller, Fitch, & Marshall, 2003)

Strategies: Define learning outcomes rather than performance goals;

3. **Own formulation of learning aims / Learning-outcome orientation**

Self-diagnosis of learning needs / learning-outcome orientation is the student's ability to acknowledge what are the goals/learning outcomes they are working for and make plans to achieve them. (Caraway, Tucker, Reinke & Hall, 2003)

Strategies: include diagnosis and formative assessments throughout education; provide ongoing feedback.

4. **Organisation of own resources / Self-efficacy**

Organisation of own resources/self-efficacy is defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances". (Bandura, 1986, in Artino, 2012, p. 77)

Strategies: promotion of independent learning; implement mechanisms to provide on-going feedback.

5. Selection of appropriate learning strategies / Metacognition

The concept metacognition is the students' ability to select the appropriate learning strategies in the right context, after analysing, reflect and understand their own learning process.

Strategies: involve students in inquiry and problem/based learning that includes problem framing, planning, data gathering, divergent thinking, idea generation, evaluating alternatives and monitoring skills.

6. Self-evaluation of learning process / Self-regulation

Self-evaluation of learning process/self-regulation is the students' ability to understand the necessary requirements and steps to complete an assignment or task and have a critical judgment the quality of the task and assignment.
Initiatives: promote through problem-solving exercises, establish strategies for developing organisation, planning, time management, identifying difficulties, solving difficulties identified, work reviewing, identifying the factors that influenced their motivation, and structure of the environment.
According to this paradigm, there are some implications for the learner and for the teacher:

1. The learner becomes aware of the need to learn
2. The learner assess whether s/he can
    a. Question and inquire
    b. Solve problems
    c. Have an open mind
    d. Scan through vast amount of data identifying the useful elements
    e. Evaluate his/her own performance with self-analysis and external feedback
    f. Observe and model others' performance for self-improvement
    g. Commit to work on the next goals
    h. Continuously motivate his/herself

For the teacher:

- Being able to provide a wide range of learning experiences
- Think about his/herself as a "facilitator of learning", a motivator, a "designer of learning situations", rather than a "teacher" per se
- Think about his/herself as learner too

3.2.2 Cross-cutting approaches of SCL and SDL

Both SCL and SDL share mutual approaches when comes to their operation, highlighting don't making them contrary but complementary and consistent, which are

3.2.3.1 Learning outcomes (LO)

As the name suggests, LOs are a description of what the learner is expected to know, understand and be able to do at the end of the learning process. They should not describe the how; while they should promote a wider knowledge base, research and innovation. Their definition, moreover, is responsibility of all stakeholders, including those outside university and should promote transparency and consistency.

Education and training institutions are increasingly describing their qualifications in terms of learning outcomes following the approach adopted by the European Qualifications Framework and by the European Higher Education Area (European Commission, 2018).

The fact that they describe the ultimate goal of the learning activities ensures that all stakeholders keep their focus during the learning/teaching process, leaving the door open to contributions based on individual experiences, and switching from a teaching activity based on "telling" to one based on "enabling". Moreover, as the individual contributions often transcend the intended LOs, any additional acquired skills should be reported separately so to document it; for instance, of the Diploma Supplement.

3.2.3.2 Problem-based Learning (PBL)

Problem-Based Learning (PBL) is an instructional method of hands-on, active learning centred on the investigation and resolution of real-world problems, originally applied in medical education during the late 1960s (Knoll, 1992). One important characteristic of this method stressed by Boud (1985) is its interdisciplinary coverage, since more than one area of knowledge is supporting the analysis and is most frequently used in higher education.

According to Gaffar & Abdalla (2011, p.8), the spelling of the word "Problems" besides encompassing the student-centred learning and self-directed learning principles and stands for the following advantages:

P – Problems (it provides the key units for structuring relevant learning)

R – Resources (use variety of resources for self-learning)

O - Objectives (learning objectives are planned by teachers, but with student input)

B – Behaviour (Students' behaviour progressively mirrors that of the profession)

L – Learning (Active and student-centred; peer and tutor monitored)

E – Examples (Establish rules and lead to higher concepts)

M – Motivation (The excitement of discovery)

S – Self-directed learning and assessment (developing the learning habit)".

On the contrary, the are some criticisms about it, such as unpreparedness of both of the professor and student.

From the professor, PBL requires extensive planning and preparation for the PBL sessions in order to facilitate the information and ask the right questions to the students. By definition, PBL is cyclical and relies in iterations to find the solution. Butler (1998) has illustrated the necessary steps to complete PBL, as illustrated in Figure 1 - Cycle of PBL, being possible to conclude that actually SCL and SDL are complementary and PBL is considered a good method to endorse both them and being used for learning and assessment purposes during the Metal AM MSc.

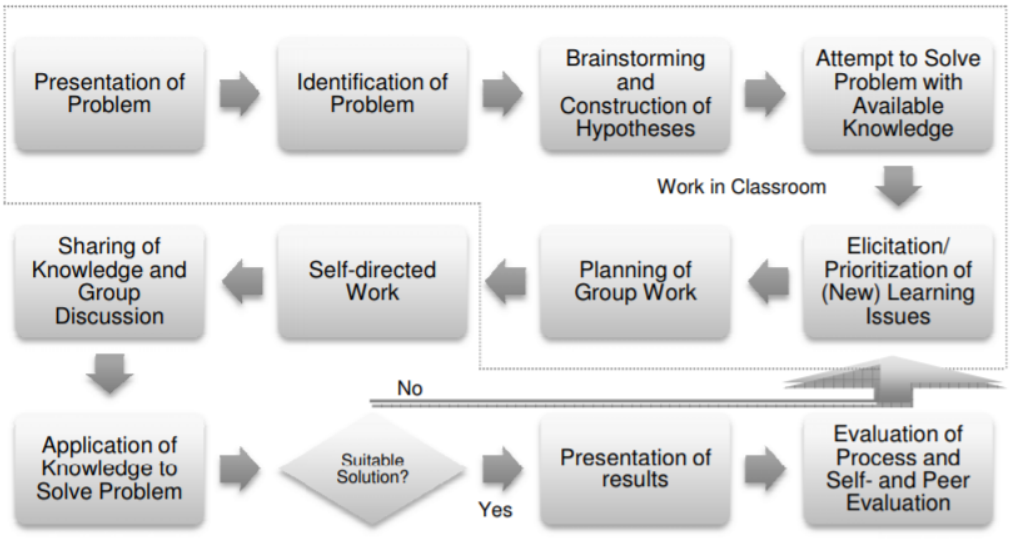

Figure 1: PBL work cycle with a problem in implementation in question.

Figure 1 - Cycle of PBL

4 Relationship between the principles and the Metal AM MSc

This section aims to explain the relationship between the principles listed previously and the strategy devised to design the Metal AM MSc. In the table below are listed which principles will support the design and how they are intended to be implemented in the MSc. The implementation might be done at macro and micro levels and echoed through some diverse initiatives: "Deliverables" or, on a smaller scale, through "Content of deliverables".

Macro level is perceived as applied in the ADMIRE project activities and Micro in design teaching and learning strategies used in some activities and deliverables. Having this assumption has reference, the initiatives have been analysed and encoded in the following way:

- MACRO – Macro level
- MICRO – Micro Level
- D. – Project Deliverable
- C.D. – Content of Deliverable

When the deliverables are already completed, is also described or listed the contents referred.

Principles underpinned to the design of the Metal AM MSc	
Principles applied to the Metal AM MSc	**How?**
Organisation of Knowledge	
3.1.3. Interdisciplinarity	Level: MACRO
	CD. 3.1: Draft Guideline of the AM MSc's Purposes and Strategies Alignment <u>Evidences</u> Mandatory Modules: - Metal AM Processes - AM Metallurgy - Design & Simulation - Management of AM quality - Economics of AM - Net-shape Manufacturing - Post-Processing - Applications Optional Modules: - Circular Economy - Product Development and Entrepreneurship

Table 1 – MSc's organisation of knowledge

How the student-centred learning principles are applied to the Metal AM MSc are listed in the following table.

Principles underpinned to the design of the Metal AM MSc	
Principles applied to the Metal AM MSc	**How?**
Learners' Centredness in Higher Education	
3.2.1 Student-Centred Learning (SCL) Principles	**How?**
1. SCL requires an on-going reflexive process	Level: MACRO
	CD. 1.1 – Report on the different AM stakeholders' perceptions - Survey on Potential MSc Students - Focus Group Meetings; CD. 2.2 – MSc's Rules and Requirements and Draft Guideline - Participation in the AM MSc Council; CD. 5.5 – Piloting of the AM Joint MSc - Participation in the pilots of the Joint Metal AM MSc CD. 6.4 – Roundtables - Feedback provided during the roundtables
2. SCL does not have a "one-size-fits-all" solution	Level: MICRO
	CD. 3.1 – Draft Guideline of the AM MSc's Purposes and Strategies Alignment - Flexible learning pathways (classroom based or problem-based learning)
3. Students have different learning styles	Level: MICRO
	CD. 3.1 - Draft Guideline of the AM MSc's Purposes and Strategies Alignment Evidences: - Learning and Assessment strategies: • Flipped classroom • Problem-based Learning • Online teaching • Blended learning • Group project • Industrial thesis.

4. Students have different needs and interests	Level: MICRO
	CD. 3.2 - Students' Support Strategies - Accessibility; - Feedback capture; - Student Advice Centre; - Career Continuation Service - Alumni Service - Exceptional circumstances and alternative arrangements in examinations (e.g. illness)
5. Choice is central to effective learning in SCL	Level: MICRO
	CD. 3.1 - Draft Guideline of the AM MSc's Purposes and Strategies Alignment Evidences Optional Modules: - Circular Economy - Product Development and Entrepreneurship
6. Students have different experiences and background knowledge	Level: MACRO
	D. 6.2 – Additive Manufacturing World Café Meetings D. 6.3 – Additive Manufacturing 'Speed Datings'
7. Students should have control over their learning	Level: MACRO
	CD. 1.1 – Report on the different AM stakeholders' perceptions - Survey on Potential MSc Students - Focus Group Meetings; CD. 2.2 – MSc's Rules and Requirements and Draft Guideline Evidences - Participation in the AM MSc Council; • Industry: 50% • Students: 25% • Scholars (university + teaching staff): 25% CD. 5.5 – Piloting of the AM Joint MSc - Participation in the pilots of the Joint Metal AM MSc CD. 6.4 – Roundtables - Feedback provided during the roundtables

8. SCL is about enabling not telling	Level: MACRO D. 4.2 - Problem-based learning assignments database; D. 6.1 - AM Hub/Platform (upload problem-based learning assignments and solve them collaboratively).
9. Learning needs cooperation between students and staff	Level: MICRO CD. 1.1 – Report on the different AM stakeholders' perceptions - Survey on Potential MSc Students - Focus Group Meetings; CD. 2.2 – MSc's Rules and Requirements and Draft Guideline - Participation in the AM MSc Council; Evidences - Participation in the AM MSc Council; • Industry: 50% • Students: 25% • Scholars (university + teaching staff): 25% CD. 5.5 – Piloting of the AM Joint MSc - Participation in the pilots of the Joint Metal AM MSc CD. 6.4 – Roundtables - Feedback provided during the roundtables

Table 2 - SCL in the Metal AM MSc

Following the same reasoning in the following table (Table 2 - SCL in the Metal AM MSc) shows the scope of Self-Directed Learning principles explained in the previous section are covered in the Metal AM MSc

Principles underpinned to the design of the Metal AM MSc	
Principles applied to the Metal AM MSc	**How?**
Self-Directed Learning in Higher Education	
3.2.2. Self-Directed Learning Principles	**How?**
1. Self-initiative by the learner / Student motivation 2. Self-diagnosis of learning needs / Learning Outcomes orientation 3. Own formulation of learning aims / Locus of control 4. Organization of own resources / Self-efficacy 5. Selection of appropriate learning strategies / Metacognition 6. Self-evaluation of learning process / Self-regulation	Level: MICRO CD. 3.1 and 5.5 – Piloting of Metal AM MSc Stage 0 – Presentation of the Goals of the MSc/learning outcomes of the courses Stage 1 – Expositive/Problem-based learning classes Stage 2 - Analysis if the LOs were accomplished Stage 3 – Mentoring/expositive classes Stage 4 – Assessment of the module

Table 3 – SDL in the Metal AM MSc

Finally, Table 4 - LOs and PBL coverage in the Metal AM MScillustrates where the learning outcomes and problem-based learning assignments are incorporated in ADMIRE's deliverables.

Principles underpinned to the design of the Metal AM MSc	
Principles applied to the Metal AM MSc	**How?**
Cross-cutting Strategies of SCL and SDL	
Learning outcomes (LO)	Level: MICRO
	CD. 3.1 - Draft Guideline of the AM MSc's Purposes and Strategies Alignment Evidences - Learning Outcomes
Problem-based Learning	Level: MACRO
	D. 4.2 - Problem-based learning assignments database; D. 6.1 - AM Hub/Platform (upload problem-based learning assignments and solve them collaboratively).

Table 4 - LOs and PBL coverage in the Metal AM MSc

5 Conclusions

This report has been insightful to understand how curricular design desires coherent choices from the beginning for a successful alignment among all the components building the Metal AM MSc.

It has been recognised that despite the fact when writing the proposal, the multidisciplinary approach to organised was the most emphasised, interdisciplinarity was perceived as the most suitable for ADMIRE project and specifically for the Metal AM MSc. This statement is valid, as important as creating an educational programme, the ADMIRE project is about defining the standards for a new profession, requiring complex knowledge, skills and abilities from the potential students.

The report shows the student-centred learning and self-directed learning are compatible, sharing some principles that are already widely implemented in Europe, such as the learning outcomes and problem-based learning methods to deliver education programmes. Additionally, student is perceived as a key stakeholder entitled to take responsibility over choices and for governance purposes.

The statements underpinning each approach (SCL and SDL) are possible and will be applied to the Metal AM MSc, at both macro and micro levels.

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