ATS STEM

Assessment of Transversal Skills in STEM

Basic Functional Requirements for Choosing VLEs and Digital Tools in ATS STEM

Contribution to D 2.1, Version 01 (Dec 2019)

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1. INTRODUCTION

1.1. Purpose

The purpose of this document is to serve as a guide for teachers participating in the ATS STEM pilot to **choose a virtual learning environment and digital tools** to support the **development of core STEM skills through formative assessment**. The core STEM skills are outlined in the ATS STEM deliverable 1.1 "STEM Education in Schools. What Research tells us!" (Dublin City University, 2019a, p. 37):

- Problem-solving
- Innovation and creativity
- Communication
- Critical thinking
- Meta-cognitive skills
- Collaboration
- Self-regulation
- Disciplinary skills and competences

This document should support teachers to make an informed choice of software and tools.

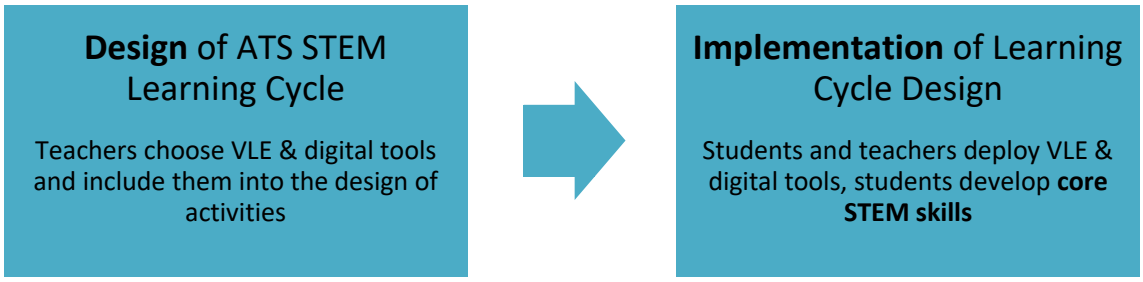

Figure 1: The role of VLEs & digital tools during the ATS STEM pilot. Each ATS STEM Learning Cycle has a STEM topic/problem to its core and contains of several learning units. A more detail description of a learning cycle you can find below in chapter 2.2.

1.2. Scope

This document contains a **description of the functionality** of a virtual learning environment and of digitals tools to support the core STEM skills development through formative assessment. It consists of a description of **functional requirements**.

Non-functional requirements are beyond the scope of this document. The description of functional requirements is based on the project's conceptual framework and therefore addressing basic aspects of supporting the implementation of learning cycles. It is not detailing on functional requirements of specific learning cycles, but rather giving an overview of minimum requirements.

This report is a contribution to D. 2.1 "Building Critical Skills in STEM: How Digital Assessment Can Give Learners Feedback". Description of the deliverable:

"A review and a synthesis of state of the art on STEM formative digital assessment with particular respect to schools. A recommendation for a key tool or platform for the project" (Dublin City University, 2018, p.65)

It recommends how suitable VLEs or platforms can be selected based on the conceptual framework of the project based on functional specifications.

1.3. Definition of terms "functional requirement" and "non-functional requirement"

"Functional requirements describe behavior and can be expressed as how an output responds to an input (or time event)." (Fulton & Vandermolen, 2017, p. 75)

The citation above reflects that the functional requirement describes the behavior of the system. Functional requirements reflect the user's expectations and they are specified in the system design. Compared to that, a non-functional requirement outlines a performance characteristic of a system. Non-functional requirements can be used to judge the operations of a system, not its specific behaviors. In this document, functional requirements are described based on the following structure:

Name	**Name of the functional requirement**
Number	Number of the requirement
Summary	Brief description of the requirement
Rationale	Description of the reason why the requirement is needed
Requirements	The required behavior
References	Use cases and other functional requirements that are relevant to understand this functional requirement.

Table 1: Functional requirement template based on Andrew & Greene (2005), p. 111

The ATS STEM requirements won't contain any design elements. Therefore, words like window, button, click, checkbox, etc. are avoided. This assures that choosing suitable virtual learning environments and digital tools is not influenced by a specific design but rather informed by the required behavior of the system. (Stellman & Greene, 2005, p. 113)

2. PROJECT CONTEXT AND REQUIREMENT ANALYSIS

2.1. Overview

Organizational Unit	K12 Schools chosen to participate at the ATS STEM pilot
Users	Teachers Students Administrators
Aim	The main aim of the ATS STEM project is to **help students to develop core STEM skills and competences through formative assessment**.
Context of Use for VLE & Digital Tools	The virtual learning environments (VLE) and digital tools are used to support the **ATS STEM learning cycles**. The learning cycles are designed for and implemented during the **ATS STEM pilot.**
Method to Reach the Aim	Teachers design and implement **learning cycles based on the ATS STEM conceptual framework**. They **use virtual learning environments and digital tools to support formative assessment**.

2.2. Conceptual Framework

The virtual learning environment and digital tools used in the ATS STEM pilot should reflect the conceptual framework as outlined in ATS STEM deliverable 1.3. "What is STEM? And how do we teach it?" (Dublin City University, 2019b) The conceptual framework has a key role in the implementation of an integrated curriculum for high quality STEM education, which was stated in the ATS STEM funding proposal:

"A framework such as this will have major implications for how teachers understand the learning domain and its perceived goals as well as the most appropriate way to organize learning activities." (Dublin City University, 2018, p. 39)

During the ATS STEM pilot, the participating teachers will **design and implement learning cycles**, which will be based on the teachers' interpretation of the conceptual framework. Each learning cycle is dedicated to an integrated STEM topic and consists of several learning units. At the start of each **learning cycle**, teachers define intended learning outcomes referring to the core STEM skills and competences together with their students.

As the **conceptual framework is central** for the design and the implementation of the ATS STEM learning cycles, it is also **the basis for the description of the functional requirements** of the virtual learning environment and tools used to facilitate formative assessment and the implementation of the learning cycles.

The conceptual framework as outlined in deliverable 1.3 contains 5 major sections:

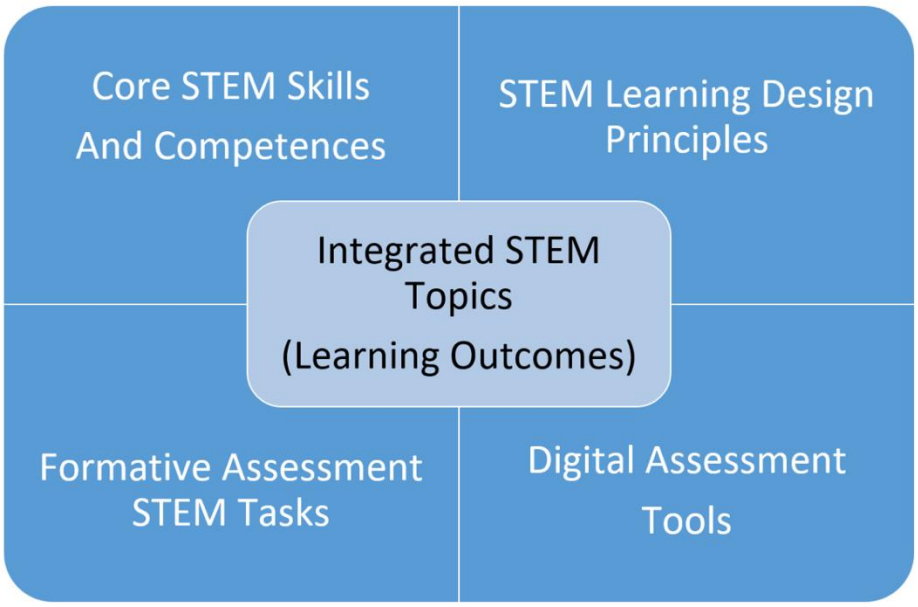

Figure 2: Visual Representation of the ATS STEM Conceptual Framework (ATS STEM D1.3, 2019, p.10)

A more detailed description of all key elements can be read in ATS STEM D1.3. (Dublin City University, 2019b) Each element contains a list of characteristics or features. The core STEM skills contain a list of **eight transversal skills and competences**. There are **six STEM learning design** principles and **12 characteristics listed for STEM tasks** focusing on formative assessment. Regarding **digital tools and VLEs, four main features** were identified.

The key elements are influencing the **design of learning cycles** in the ATS STEM pilot. A generic learning cycle design follows a basic structure, considering the conceptual framework in each stage (based on Economou, 2018):

1. **Start of the ATS STEM learning cycle**: Defining intended learning outcomes, considering prior learning experiences and referring to the core STEM skills.
2. **Planning learning activities** and tasks together with students, considering STEM learning design principles and characteristics of STEM tasks.
3. **Learning, collecting evidence, continuous formative feedback**, considering STEM learning design principles and characteristics of STEM tasks.
4. **End of the ATS STEM learning cycle**: Checking if intended learning outcomes can be shown and lessons learned are defined as a basis for planning the next learning cycle. (considering STEM learning design principles and characteristics of STEM tasks)

The VLEs and digital tools should support the implementation of formative assessment methods in the ATS STEM learning cycles in order to support the development of the identified core STEM skills.

2.3. Further Information

To better understand the functional requirements, it is recommended to study following documents:

- A categorization as well as lists of virtual learning environment and digital tools useful for formative assessment are included in the report for ATS STEM workpackage 2, task 1 and 2. (Szendey & O'Leary, 2019, p. 5 as well as appendix A and F)
- The requirement analysis mainly relies on the definition of core STEM skills as outlined in the results of the ATS STEM literature review in D 1.1 (Dublin City University, 2019a) as well as on the conceptual framework identified in D 1.3. (Dublin City University, 2019b)
- The description of functional requirements for ATS STEM is based on the structure of the Software Requirements Specification Template by Stellman & Greene. (2005, p. 110ff.)

3. FUNCTIONAL REQUIREMENTS

The conceptual framework identifies four main features of virtual learning environments and digital tools supporting formative assessment for an integrated STEM education (Dublin City University, 2019b, p. 22):

- **Functionality:** It supports sending and displaying, processing and analyzing in an interactive environment.
- **Flexibility:** It supports the assessment of different types of learning.
- **Practicality:** It requires teacher professional development but is relatively easy and cost effective to use.
- **Usefulness:** It helps to improve learning by facilitating timely feedback focused on learning outcomes/goals (the consequential validity argument).

Based on the four features, functional requirements for VLEs and digital tools in the ATS STEM pilot are described in this document.

3.1. Key Features of VLEs and digital tools No.1: Functionality

The VLE and/or digital tools need to be functional during the ATS STEM learning cycles. They need to support functions like sending and displaying, processing and analyzing in an interactive environment (Dublin City University, 2019b, p. 22):

- **"Sending and Displaying:** These are actions that **facilitate communication between the different actors in the formative assessment process**; they can the thought of as facilitating the elicitation and student response processes. A classroom response system where students reply to items using phones or tablets and results are displayed for the class would be an example of this." (FR 1, 2, 3)
- **Processing and Analyzing:** These are actions where technology supports the **interpretation phase of formative assessment**, such as **extracting or summarizing relevant data**. An example of this would be a data dashboard summarizing student performance." (FR 4, 8, 5, 6, 7)
- **Providing an Interactive Environment:** These are actions that enable students to **work individually or collaboratively to explore content** and may include features from the other two categories. Examples of this are specialized software for allowing students to explore geometrical drawings or other specific topics." (FR 5, 6, 7)

Each of the three aspects listed above may be useful for any of the following five formative assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21)

- Clarifying, sharing, and understanding learning intentions and criteria for success; (FR 1, 2, 4)
- Engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; (FR 3, 4, 5, 6, 7)
- Providing feedback that moves learners forward; (FR 3, 4, 5, 6, 7, 8)
- Activating students as instructional resources for one another; (FR 3, 5, 6, 7)
- Activating students as owners of their own learning. (FR 1, 2, 4, 8)

Based on the feature "functionality" and its three aspects, the following eight functional requirements can be described:

Name	**Send and display learning outcomes**
Number	FR 1
Summary	Students and teachers can send and display learning outcomes.
Rationale	The definition of learning outcomes is the **basis for all activities planned** at the start of a learning cycle. Furthermore, they serve as a benchmark for formative assessment and are therefore an important aspect of **transparent assessment**. The requirement supports the **interpretation phase of formative assessment**, as the clear communication of learning outcomes is a prerequisite. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: • Clarifying, sharing, and understanding learning intentions and criteria for success; • Activating students as owners of their own learning.
Requirements	Students as well as teachers can send intended learning outcomes and the VLE and/or digital tools display the learning outcomes.
References	The following feedback design pattern is connected with the requirement: • Learning Contract by Larson et al. 2008 (Grundschober, 2017b) FR1 is closely connected with: • FR3 Match learning outcomes with learning artefacts • FR2 Sending, displaying and sharing an assessment criteria list

Name	**Sending, displaying and sharing an assessment criteria list**
Number	FR 2
Summary	Students and teachers can create and share an assessment criteria list.
Rationale	An assessment criteria list is **deriving from learning outcomes and supports transparent assessment**. Assessment criteria should be **created together** with students and clearly communicated to prevent students from running in the wrong direction and perform poorly. The requirement supports the **interpretation phase of formative assessment**, as the clear communication of learning outcomes is a prerequisite. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: • Clarifying, sharing, and understanding learning intentions and criteria for success; • Activating students as owners of their own learning.
Requirements	The VLE and/or digital tools allow teachers and students to send, display and share an assessment criteria list.
References	The following feedback design pattern is connected with the requirement: • Assessment Criteria List by Bergin et al. 2015 (Grundschober, 2017a)

Name	**Upload, display and share learning artefacts**
Number	FR 3
Summary	Students can upload and share learning artefacts with teachers and peers.
Rationale	In order to continuously give and receive feedback, students **first need to share their learning artefacts** with others. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: Engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; • Providing feedback that moves learners forward; • Activating students as instructional resources for one another.
Requirements	Students can upload learning artefacts and the VLEs and/or tools displays them, so teachers and peers can see and reflect on them.
References	The following feedback design pattern is connected with the requirement: • Student Online Portfolio by Eckstein, Bergin, Sharp, & Manns, 2002a, p. 11 (Grundschober, 2017d)

Name	**Match learning outcomes and assessment criteria with learning artefacts and artefact collections**
Number	FR 4
Summary	Teachers and students can link learning artefacts or artefact collections with learning outcomes and assessment criteria.
Rationale	To support formative assessment and reflection, the learning environment should enable students and teachers to **match learning outcomes and assessment criteria with learning artefacts and/or artefact collections**. The requirement supports the **interpretation phase of formative assessment**. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: • Clarifying, sharing, and understanding learning intentions and criteria for success; • Engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; • Providing feedback that moves learners forward; • Activating students as owners of their own learning.
Requirements	The VLE and/or the digital tools allow linking learning outcomes and assessment criteria with learning artefacts and/or artefact collections.
References	FR4 is closely connected with FR 1, 2, 3, 5 The following feedback design pattern is connected with the requirement: • Self-Evaluation by Bauer & Baumgartner 2012 (Grundschober, 2017b)

Name	**Create, display and share collections of learning artefacts**
Number	FR 5
Summary	Students and teachers can create and share collections of learning artefacts. They can either create collections individually or collaboratively.
Rationale	To support and document the activities during a ATS STEM learning cycle, students as well as teachers can **create collections of learning artefacts**. Students can work **individually or collaboratively** to **explore content, to document and to structure their findings**. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: • Engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; • Providing feedback that moves learners forward; • Activating students as instructional resources for one another.
Requirements	The VLEs and/or tools allow to create a collection of learning artefacts and to display it. The collections can be shared among students and teachers. The collections can be either created individually or collaboratively in groups.
References	The following feedback design pattern is connected with the requirement: • Student Online Portfolio by Eckstein, Bergin, Sharp, & Manns, 2002a, p. 11 (Grundschober, 2017d)

Name	**Comment artefacts**
Number	FR 6
Summary	Students and teachers can comment learning artefacts.
Rationale	To support formative assessment and reflection, the VLE and/or digital tools should enable students and teachers to comment on learning artefacts. The requirement supports the **interpretation phase of formative assessment**. Furthermore, it **facilitates communication** between the different actors in the formative assessment process. FR 6 enables **peer evaluation**. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: • Engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; • Providing feedback that moves learners forward; • Activating students as instructional resources for one another.
Requirements	The VLEs and/or tools allow teachers and students to comment learning artefacts in an asynchronous way.
References	The following feedback design patterns are connected with the requirement: • Feedback by Bergin, Eckstein, Manns, & Wallingford, 2001(Grundschober, 2017a) • Reflection by Bergin, Eckstein, Manns, & Wallingford, 2001(Grundschober, 2017c)

Name	**Chatting**
Number	FR 7
Summary	Students and teachers can chat and exchange asychronically as well as synchronically.
Rationale	To support formative assessment and reflection, the VLE and/or digital tools should enable students and teachers to **chat and exchange asynchronically as well as synchronically**. The requirement supports the **interpretation phase of formative assessment**. Furthermore, it **facilitates communication** between the different actors in the formative assessment process. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed: • Engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; • Providing feedback that moves learners forward; • Activating students as instructional resources for one another.
Requirements	The VLE and/or digital tools allow teachers and students to chat and exchange about learning artefacts, learning outcomes and learning activities asynchronically as well as synchronically.
References	Examples of asychronous communication are private messages or mails. Examples for synchronous communication are chats. There are examples of functions that allow both, eg. a forum or messengers like slack or whatsapp. The following feedback design patterns are connected with the requirement: • Feedback by Bergin, Eckstein, Manns, & Wallingford, 2001(Grundschober, 2017a) • Reflection by Bergin, Eckstein, Manns, & Wallingford, 2001(Grundschober, 2017c)

Name	**Summarized data on student performance**
Number	FR 8
Summary	Students and teachers get an overview about summarized data on student performance.
Rationale	To support formative assessment and reflection, the learning environment should enable students and teachers to get an **overview** about summarized data on student performance in the VLE. The requirement supports the **interpretation phase of formative assessment** and helps to **process and analyze the student performance**. Following assessment strategies (Wiliam & Thompson, 2017 and Dublin City University, 2019b, p. 21) are addressed:

	• Providing feedback that moves learners forward; • Activating students as owners of their own learning.
Requirements	The VLE and/or digital tools allow teachers and students understand the latest student performance and learning progress through a data summary based on activities in the VLE and/or using digital tools.
References	An example for the visualization of data summaries on student performance are data dashboards in VLEs. They could show latest activities in a learning group, changes in an artefact collection, results of exams or progress on a learning path. The following UI design pattern describes how to use FR8: • Dashboard ('Dashboard design pattern', n.d.)

3.2. Key Features of VLEs and digital tools No.2: Flexibility

The VLE and/or digital tools support the **assessment of different types of learning**, including following points (Dublin City University, 2019b, p. 23):

- Providing differentiation (supported by FR 9, 10)
- Collaborative learning (supported by FR 5, 6, 7)
- Peer evaluation (supported by FR 6, 7)
- Responsiveness
- Accessibility for students with disability (non-functional requirement)

Responsiveness and accessibility were mentioned as aspects of flexibility for VLEs and digital tools. As they are defined as **non-functional requirements** (see also 'Nonfunctional Requirement Examples', n.d.), therefore these requirement descriptions are beyond the scope of this document.

Based on the feature "flexibility", the following two functional requirements can be described:

Name	**Various question types**
Number	FR 9
Summary	Students and teachers can use a variety of questions types to explore and reflect a certain STEM topic.
Rationale	To support formative assessment and reflection, the learning environment should enable students and teachers to use various question types – **not only "open questions", multiple-choice or single-choice questions**. Various questions types can support applying tasks in a **dynamic and/or extended context**, providing more **nuanced information** about a certain STEM topic to explore and reflect. (Dublin City University, 2019b, p. 23) Each question type addresses different cognitive skills. Based on the cognitive level of the intended learning outcomes of a learning cycle, a **more appropriate choice of question types** to support the learning process can be made, especially if there are various question types available. Furthermore, students can benefit from various question types when designing tests or **exams for peers**.
Requirements	The VLEs and/or digital tools allow teachers and students to use a variety of question types.
References	Examples for various question types provided by the learning management system Moodle are listed in the official user guide for Moodle (Moodle, n.d.).

Name	**Automated feedback**
Number	FR 10
Summary	Students are provided with automated feedback based on their inputs in the VLE or based on their activities using digital tools.
Rationale	To support formative assessment and reflection, the learning environment should provide students with automated feedback during the learning process. This can be especially useful when students are **completing inquiry-based tasks**. Automated feedback supports **immediate response** for students on how to proceed on their learning pathway. Furthermore, automated feedback allows **differentiation** based on the individual student's inputs. (Dublin City University, 2019b, p. 23)
Requirements	The VLEs and/or digital tools provide automated feedback on students' inputs. FR 10 only applies to student data, which was captured in a structured manner.
References	FR 10 is closely connected to FR 9 "Various question types". Furthermore, it is connected to FR8 "Summarized data on student performance", as on data dashboards summarized results of automated feedback could be displayed. FR 10 could be based on FR 9 "Send and display learning outcomes" and FR 2 "Sending, displaying and sharing an assessment criteria list" as reference points.

3.3. Key Features of VLEs and digital tools No.3 & 4: Practicality & Usefulness

"Several studies indicate that teachers require appropriate support and training in order to successfully integrate digital tools into their classrooms and that perceived benefits and ease of use are important factors for teachers when considering digital tools." (Dublin City University, 2019b, p. 23)

Regarding perceived ease, the VLEs and digital tools used during the ATS STEM pilot need to consider **usability** regarding the main target user community (teachers and learners). Usability is defined as a **non-functional requirement** (see also 'Nonfunctional Requirement Examples', n.d.) and is therefore not included into this document.

Regarding the aspect of **perceived benefits**, support and training could be provided by an **onboarding-system for teachers as well as students**, which could be integrated into the VLEs and digital tools:

Name	**Onboarding-system for teachers and students**
Number	FR 11
Summary	*"The user needs to acquire the necessary knowledge, skills, and behaviors to become effective."* ('Design patterns: Onboarding', n.d.) Therefore, when first using new VLEs or digital tools, students and teachers are supported by an onboarding-system. It helps them to get acquainted with new functions and features as well as supporting them to gain awareness about the benefits of the VLE and tools for the learning process.
Rationale	An onboarding-system helps teachers and students to get acquainted with new functions and features as well as supporting them to **gain awareness about the benefits of the VLE and tools for the learning process**. It helps them to use the VLE and digital tools **more effectively** during the ATS STEM learning cycles.
Requirements	The VLEs and/or digital tools provide an onboarding-support for first-time users, guiding them through the functions of the VLE and digital tools.
References	Several UI-patterns exist, describing various onboarding-solutions (see also 'Design patterns: Onboarding', n.d.): • Walkthrough • Blank Slate • Coachmarks • Playthrough • Guided Tour • Inline Hints

4. HOW TO USE THE REQUIREMENT DESCRIPTIONS

The list of functional requirements FR 1-11 describes basic functions necessary to support the development of core STEM skills through the implementation of ATS STEM learning cycles using VLEs and digital tools for continuous formative assessment.

The requirement list serves as a general guide for teachers to choose VLEs and/or digital tools. It is intended to be used for assessing one's current or envisioned setup of digital tools and identify potential gaps or limitations. Depending on the planned form of formative feedback and the pedagogical setting it is deployed in, some requirements might not be as relevant as others. The "rationale"-section available for each of the requirements indicates the potential use cases and provides input for individually assessing their relevancy for one own's setting.

5. LIMITATIONS

Please mind, that FR 1-11 are of rather general nature, as the supporting information at the moment is on a rather abstract level. For more detailed requirements, a more detailed picture of the learning and teaching process is needed. This could be a generic design template for the ATS STEM learning cycles (including generic activities, see also description of D 2.3 and 2.4, p. 65 of the ATS STEM project proposal).

6. GLOSSARY

Term	Definition
Artefact/ Artifact	A learning artefact is an object created by students during a learning cycle. *"Constructionism has articulated a more distributed view of instruction, one where learning and teaching are constructed in interactions between the teacher and students as they are engaging in design and discussion of learning artifacts."* (Kafai, 2006, p. 36)
Functional Specification	*"Functional requirements describe behavior and can be expressed as how an output responds to an input (or time event)."* (Fulton & Vandermolen, 2017, p. 75)
Non-functional Specification	Non-functional requirements can be used to judge the operations of a system, not it's specific behaviours.
Learning Cycle	During the ATS STEM pilot, the participating teachers will **design and implement learning cycles**, which will be based on the teachers' interpretation of the conceptual framework. Each learning cycle is dedicated to an integrated STEM topic and consists of several learning units.
Design Pattern	*"A pedagogical pattern is the re-usable form of a solution to a problem or task in pedagogy, analogous to how a design pattern is the re-usable form of a solution to a design problem. Pedagogical patterns are used to document and share best practices of teaching. A network of interrelated pedagogical patterns is an example of a pattern language."* ('Pedagogical pattern', 2019)

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