Interactive Music Science Collaborative Activities

Team Teaching for STEAM Education

Deliverable 2.2

Initial Evaluation metrics for deeper learning with iMuSciCA

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Executive Summary

This deliverable reports on the initial evaluation metrics for deeper learning with iMuSciCA. This evaluation metrics will be used during the piloting phases of the project and it will be based on an iterative process of responsive evaluation. The results of this evaluation will form the basis for a cycle of optimization of the iMuSciCA learning environment. The aim of the evaluation is to see if iMuSciCA can address deeper learning in a reasonable way and to provide valuable information on how to improve the iMuSciCA environment to this purpose. First, we provide a description of deeper learning, its competences and the corresponding expected student outcomes. Then, we propose a selection of these outcomes that will form the criteria for the evaluation metrics. Finally, we describe the four methods that will be implemented in order to get the desired feedback.

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

Abbreviation	Description
PU	Public Report
WP	Work Package
STEM	Science, Technology, Engineering and Maths
STEAM	Science, Technology, Engineering and Maths combined with Arts
ATHENA	ATHENA RESEARCH AND INNOVATION CENTER IN INFORMATION COMMUNICATION & KNOWLEDGE TECHNOLOGIES
UCLL	UC LIMBURG
EA	ELLINOGERMANIKI AGOGI SCHOLI PANAGEA SAVVA AE
IRCAM	INSTITUT DE RECHERCHE ET DE COORDINATION ACOUSTIQUE MUSIQUE
LEOPOLY	3D FOR ALL SZAMITASTECHNIKAI FEJLESZTO KFT
CABRI	Cabrilog SAS
WIRIS	MATHS FOR MORE SL
UNIFRI	UNIVERSITE DE FRIBOURG

1. Introduction

One of the aims of STEAM education is to promote aspects of education that cannot be addressed within single discipline teaching. These aspects can refer to the content of learning as well as to the context and approaches of learning (Honey et al., 2014; Quigley et al., 2017; Czerniak & Johnson, 2007).

As iMuSciCA follows an interdisciplinary STEAM approach, it helps create the awareness that, only by discovering different aspects of the same, we can see more: the 'more' that you cannot see when you stay within one discipline. STEAM works on the transfer of concepts and skills from one content area to another. It examines the same phenomenon in different ways and from different stances (Quigley et al., 2017; Frans et al., 2013).

The inclusion of concepts or practices from different subject areas in iMuSciCA is intended to deepen the learning and the understanding of the targeted STEAM subjects. The hypothesis of the iMuSciCA project is furthermore that learners can interact with these different viewpoints of STEAM, that these interdisciplinary views will free deep motivation of learners for the STEAM-world. This will also be assessed during the piloting.

Based on the aims of the envisaged STEAM pedagogy and the characteristics of deeper learning, criteria are defined for evaluating the STEAM pedagogy during the piloting phase. On the basis of these criteria the pilot testing will be set up quantitatively and qualitatively (see WP6). The evaluation will consist of observations, questionnaires and in depth-interviews in combination with the gathering of information by user monitoring tools (see WP6). Because it is impossible to measure deeper learning in a few lessons, the deeper learning evaluation will be applied in the 'heavier' type of school implementations. This will form the basis for a cycle of optimization of iMuSciCA.

The outcome of this deliverable is to give a) the rationale behind the chosen criteria and b) provide a list of criteria for evaluation of the envisaged STEAM pedagogy. This list will be applied into the envisaged piloting methodology in order to be used in the pilot testing in the schools. These criteria will be part of the pedagogical guide too and are input for WP6 on the pilot testing.

2. The application of deeper learning in iMuSciCA

Deeper learning is opposed to superficial or 'thin' learning (Jensen, E., & Nickelsen, L., 2008). According to the Hewlett Foundation (https://www.hewlett.org/programs/education/), deeper learning includes the following competences:

(1) Mastering rigorous academic content
(2) Thinking critically
(3) Working collaboratively
(4) Communicating effectively
(5) Learning to learn
(6) Developing academic mindsets.

Figure 1. Classification of competences included in Deeper Learning

We will give a short explanation of each of these competences in terms of related student outcomes, and identify those iMuSciCA will focus on (showed below in bold). Indeed the outcomes specified by the Hewlett Foundation refer to what "graduate students from high school should be equipped to". iMuSciCA however does not deal with graduates, but with younger students (from 10 up to 17 years old students). For this reason not all, but part of the given outcomes will be assessed in iMuSciCA.

2.1. Mastering rigorous academic content

Students develop and draw from a baseline understanding of knowledge in an academic discipline and are ***able to transfer knowledge*** to other situations.

- **1a Students understand key principles and relationships within a content area and organize information in a conceptual framework**
- **1b Students learn, remember, and recall facts relevant to a content area**
- **1c Students learn and can apply theories relevant to a content area**
- **1d Students have procedural knowledge of a content area and know how content knowledge is produced and how experts solve problems.**
- **1e Students know and are able to use the language specific to a content area**
- **1f Students extend core knowledge to novel tasks and situations in a variety of academic subjects**
- **1g Students enjoy and are able to rise to challenges requiring them to apply knowledge in nonroutine ways.**
- **1h Students apply facts, processes, and theories to real world situations.**

Importance for iMuSciCA: The transfer of knowledge is at the heart of the envisaged iMuSciCA STEAM pedagogy. More precisely the transfer of knowledge between the STEAM fields included in the iMuSciCA pedagogy, i.e. Science and Math, Engineering and Technology, Music. Therefore, this competence 'Master Core Academic Content' will form a core part of the evaluation.

2.2. Thinking critically

Students apply tools and techniques gleaned from core subjects to formulate and solve problems. These tools include data analysis, statistical reasoning, and scientific inquiry as well as creativity, nonlinear thinking, and persistence.

2a Students are familiar with and able to use effectively the tools and techniques specific to a content area.

2b Students formulate problems and generate hypotheses.

2c Students identify data and information needed to solve a problem.

2d Students apply tools and techniques specific to a content area to gather necessary data and information.

2e Students evaluate, integrate, and critically analyze multiple sources of information.

2f Students monitor and refine the problem-solving process as needed, based on available data.

2g Students reason and construct justifiable arguments in support of a hypothesis.

2h Students persist to solve complex problems.

Importance for iMuSciCA: Problem solving and using tools of different disciplines is the operational counterpart of the academic knowledge. The pedagogy (see *D2.1-Initial Pedagogical framework and iMuSciCA use cases by learners and teachers*) in the different inquiry phases, addresses the tools of the different STEAM fields. Thinking in different disciplines, connecting them and solving problems is in the pedagogy. So critical thinking and solving problems will be part of the evaluation. Only outcomes 2f, aiming at students monitoring and refining the problem-solving process, and 2h, aiming at 'complex' problems, are less applicable in the iMuSciCA school contexts, given the target age group of iMuSciCA. Indeed these are advanced competences and we can not expect pupils of this age group to fully acquire and exploit them. In any case we can not expect to measure the effect of the project on these two criteria, given the relatively short implementation time.

2.3. Working collaboratively

Students cooperate to identify and create solutions to academic, social, vocational, and personal challenges.

3a Students collaborate with others to complete tasks and solve problems successfully.

3b Students work as part of a group to identify group goals.

3c Students participate in a team to plan problem-solving steps and identify resources necessary to meet group goals.

3d Students communicate and incorporate multiple points of view to meet group goals.

Importance for iMuSciCA: Collaborative Learning is precisely one of the **pedagogical methods** behind iMuSciCA. In the inquiry phases, especially in the 'communicate and reflect' phase, collaborative learning is the order of the day. Therefore this will be an integral part of the evaluation.

2.4. Communicating effectively

Students clearly organize their data, findings, and thoughts.

4a Students communicate complex concepts to others in both written and oral presentations.

4b Students structure information and data in meaningful and useful ways.

4c Students listen to and incorporate feedback and ideas from others.

4d Students provide constructive and appropriate feedback to their peers.

4e Students understand that creating a quality final communication requires review and revision of multiple drafts.

4f Students tailor their message for the intended audience.

Importance for iMuSciCA: Effective communication is addressed in one of the inquiry phases in the iMuSciCA pedagogy. Therefore, this will be an integral part of the evaluation. Only 4e and 4f are less applicable in the iMuSciCA school contexts due to boundaries of time and the audiences will be mostly school related audiences.

2.5. Learn to learn

Students monitor and direct their own learning.

5a Students set a goal for each learning task, monitor their progress towards the goal, and adapt their approach as needed to successfully complete a task or solve a problem

5b Students know and can apply a variety of study skills and strategies to meet the demands of a task.

5c Students monitor their comprehension as they learn, recognize when they become confused or encounter obstacles, diagnose barriers to their success, and select appropriate strategies to work through them.

5d Students work well independently but ask for help when they need it

5e Students routinely reflect on their learning experiences and apply insights to subsequent situations

5f Students are aware of their strengths and weaknesses, and anticipate needing to work harder in some areas

5g Students identify and work towards lifelong learning and academic goals

5h Students enjoy and seek out learning on their own and with others

5i Students anticipate and are prepared to meet changing expectations in a variety of academic, professional and social environments.

5j Students delay gratification, refocus after distractions, and maintain momentum until they reach their goal.

5k Students use failures and setbacks as opportunities for feedback and apply lessons learned to improve future efforts.

5l Students care about the quality of their work and put in extra effort to do things thoroughly and well.

5m Students continue looking for new ways to learn challenging material or solve difficult problems.

Importance for iMuSciCA: Due to its envisaged pedagogy, iMuSciCA will focus here on 5d (work independently while asking for help when needed) because this is part of the iMuSciCA pedagogical method, 5e (reflection and applying insights to other situations) because of the interdisciplinary pedagogy, on 5h (joy of learning) because of the envisaged motivation, 5j (maintain momentum until the goal) and 5l (quality of work) because these fall in the scope of deeper learning. Therefore these will be an integral part of the evaluation.

2.6. Developing academic mindsets

Students develop positive attitudes and beliefs about themselves as learners that increase their academic perseverance and prompt them to engage in productive academic behaviours. Students are committed to seeing work through to completion, meeting their goals, and doing quality work, and thus search for solutions to overcome obstacles.

I belong in this academic community:

a. Students feel a strong sense of belonging within a community of learners and value intellectual engagement with others.
b. Students understand learning as a social process and actively learn from one another and support each other in pursuit of learning goals.
c. **Students readily engage in the construction of meaning and understanding through interaction with peers.**

I can succeed at this:

d. **Students trust in their own capacity and competence and feel a strong sense of efficacy at a variety of academic tasks.**
e. Students see themselves as academic achievers and expect to succeed in their learning pursuits.

My ability and competence grow with my effort:

f. **Students believe that hard work will pay off in increased knowledge and skills.**
g. **Students are motivated to put in the time and effort needed to build a solid knowledge base and to accomplish important goals.**

This work has value for me:

h. **Students perceive the inherent value of content knowledge and of learning and developing skills.**
i. **Students see the relevance of school work to their lives and interests.**
j. **Students understand how work they do now will benefit them in the future.**
k. **Students know that future learning will build upon what they know and learn**

Importance for iMuSciCA: iMuSciCA will focus here on c (construction of meaning through interaction with peer), because of the collaborative pedagogy, on d (trust in their own capacity and competence), because of the pedagogical method and the interdisciplinarity, and on f, g, h, i, j, k because of the envisaged motivation and quality of work.

3. The metrics for the iMuSciCA evaluation

3.1. The metrics reflects the piloting methodology

We will now come to all that will be applied into the envisaged piloting methodology. This pilot testing foresees observations, in-depth interviews and/or focus groups, and questionnaires. Because deeper learning requires more than a few lessons, the evaluation of deeper learning will be applied in the iMuSciCA schools with heavier implementation (see *D6.1-Pilot testing action plan*).

Indeed, as competencies ought to be observed in real settings, iMuSciCA will evaluate the deeper learning by observation, and organising questionnaires and interviews or focus groups of students and practitioners in the classroom. As described in D6.1, the piloting phases in the evaluation will be based on an iterative process of responsive evaluation (Abma & Stake, 2001 ; Youker, 2005) with aim the improvement of the (i) pedagogical fit and value and (ii) the learning fit and value. This evaluation will form the basis for a cycle of optimization of the iMuSciCA learning environment. Therefore the metrics will be manageable in a school context (without disturbing too much the daily lessons) and will at the same time provide feedback on how to improve the implementation. It is important to note that the iMuSciCA deeper learning metrics has no claim to be a better methodology compared to any other methodology: for this reason no control groups will be used. The aim of the evaluation is to see if iMuSciCA can address deeper learning in a reasonable way and above all the metrics should provide detailed and valuable qualitative information on how to improve the iMuSciCA environment. The iMuSciCA approach is an innovative one and positive deeper learning results by students and associated positive evaluation by teachers would be sufficient to claim the merits of this new approach, which is based on a strong pedagogical conceptual framework.

The developed metrics of deeper learning will give outermost attention to the real reactions of the teachers and students themselves, as given in authentic class observations, observations of students activities as well as experiences reported during interviews or focus groups. These qualitative inputs can be supplemented by questionnaires, especially where ‘core content’, ‘critical thinking and problem solving’ and ‘develop academic mindsets’ are concerned. This way we avoid working with long lists of criteria that are both not manageable in the practice of a school and also give mostly very poor information about the ‘why’ and ‘what can be done to improve’. It is indeed especially the latter which is of importance for iMuSciCA: going through an iteration process of improvement.

The outcome of this whole process of the evaluation metrics will be concrete suggestions to improve the technical usability, pedagogical fit and learning fit.

3.2. Metrics for the iMuSciCA evaluation

In the pilot testing the different deeper learning competencies are addressed in with: observation, thematization in a focus group (students) or in-depth interviews (teachers), questionnaires to teachers and students and human-computer interaction. These four methods, combined with the deeper learning competencies, form a practicable manageable and valuable methodology at the

same time. It is valuable because it will give good feedback on how the iMuSciCA environment should be improved. Below you find the scheme of the iMuSciCA evaluation methodology (Table 1).

Deeper learning competencies promoted in iMuSciCA	**Observation**	**Student focus group** (small group of 10) and **teacher in-depth interview**	**Questionnaires** (to students and teachers)	**Human-Computer Interaction**
(1) Mastery of core academic content	Do students **acquire** the **core concepts** intended in the scenarios? Likert scale 1-5	**Students reflect** on their learning of core concepts of the different STEAM fields by looking at and commenting on their work. **Teachers** are asked to **comment** on the learning of their students and in particular of the 10 'focus' students.	**i) Student Questions** around the **core concepts**. Students have to **explain their rationales** (Likert scale 1-5 self evaluation by students compared with the results of content tests) **ii) Question the teacher about this item**.(Likert scale 1-5)	**Answers to questions embedded in lesson plans** will be saved and reviewed by teachers and researchers.
(2) Critical thinking and problem-solving	Can students **apply** the appropriate **tools** and **techniques for problem solving in** the different STEAM disciplines involved in iMuSciCA? Likert scale 1-5	**Students Reflect** on their application of problem solving tools and interdisciplinary thinking by looking back at their accomplished work. **Teachers comment** on these issues.	**i) Student Questions** about applying **core problem solving tools** (Likert scale 1-5 self evaluation by students compared with Likert scale of teachers) **ii) Question the teacher about this item** (Likert scale 1-5)	**Details about the use by pupils (choice, time they spent) of particular tools on the workbench** (provided by the iMuSciCA tracking system), in relation to specific activities in the lesson plans.

(3) Working collaboratively in groups	Students push each other to explain their thinking and ideas. Can students work collaboratively with others to complete tasks and solve problems? Likert scale 1-5	**Students reflect** on the way they could: - work independently - used the complementary skills of every group member at the same time.	**Question the teacher about this item** (Likert scale 1-5)	**Interactions between students; sharing of resources; information exchange**
(4)Communicating clearly and effectively	**Can students give** each other **constructive feedback**? Do the **listen to others' feedback and ideas**, and are they prepared to **incorporate it** in their thinking? Likert scale 1-5	Students and teachers reflect on the quality of the delivered work.	**Question the teacher about this item** (Likert scale 1-5)	
(5) Learning how to learn	Do students ask content-related questions to themselves, to peers and teachers Likert scale 1-5	Students reflecting on their progress, using discussions with teachers and peers to keep up their own learning	i) Students' Questionnaire (Likert scale 1-5 self evaluation by students compared with the results of teachers) ii) **Question the teacher about this item** (Likert scale 1-5)	Any communication between student and teacher, or amongst students via the Moodle platform.
(6) Develop academic mindsets.	Students are motivated to put in the time and effort needed to build a solid knowledge base and to accomplish important goal. Likert scale 1-5	Students reflect on their effort.	**Question the teacher about this item** (Likert scale 1-5) **Student motivation questionnaire**	**Student behavioural and biometrical data.**

Table 1. Scheme of the iMuSciCA evaluation methodology

The result of the threefold evaluation give feedback whether iMuSciCA is addressing these deeper learning competences and above all, from the observations, interviews, focus groups and questionnaires, various inputs will become available on the basis of which the iMuSciCA learning environment will be optimised.

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