Grant Agreement No.: 871573
Call: H2020-ICT-2019-2
Topic: ICT-30-2019-2020
Type of action: CSA

D1.1 DEL4ALL TECHNOLOGY VS. EDUCATION MATRIX

Revision: v.1.0

Work package	WP 1
Task	Task 1.1
Due date	30/04/2020
Submission date	02/06/2020
Deliverable lead	OU
Version	1.0
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Abstract	In order to map the landscape of digital education activity in Europe, we describe the data model for the crowdsourcing of activities and actors in this area, and present a first version of a mapping between technologies and the various aspects of educational context in which they are being used. This data model will provide a basis for the bottom-up modelling of the best pedagogical uses of technology, in order to update this mapping, and to help clarify and prioritise research agendas and policy recommendations to maximise impact.
Keywords	Digital education, online pedagogy, resilience, decentralisation

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	01/04/2020	1st version of the deliverable for comments	Allan Third (OU)
V0.3	20/04/2020	Updated with more description & new version of diagrams	Allan Third (OU)
V0.4	24/04/2020	Complete draft after comments	Allan Third (OU), Alex Grech (3CL), Sabine Kolvenbach (FI)
0.5	30/04/2020	Revisions after comments	Allan Third (OU), Alex Grech (3CL), Sabine Kolvenbach (FI)
0.6	27/05/2020	Further revisions and restructuring	Allan Third (OU), Alex Grech (3CL), Sabine Kolvenbach (FI)
0.7	29/05/2020	Expanded text and examples	Allan Third (OU), Alex Grech (3CL), Sabine Kolvenbach (FI)
1.0	02/06/2020	Formatting and final update	Martel

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PU	Public, fully open, e.g. web	✔
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CO	Confidential to DEL4ALL project and Commission Services	

** R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

EXECUTIVE SUMMARY

DEL4ALL Technology vs. Education Model and Matrix:

Now, perhaps more than ever, it is important to ensure that digital education is *learner-focused*, *inclusive*, and *resilient*, and that technology is applied effectively and appropriately.

Educational technologies provide different forms of value, and pose different challenges, depending on the educational context of use, and the stakeholders involved. In order to map the landscape of digital education activity in Europe, we describe the data model for the crowdsourcing of activities and actors in this area and present a first version of a mapping between technologies and the various aspects of educational context in which they are being used. This data model will provide a basis for the bottom-up modelling of the best pedagogical uses of technology, in order to update this mapping, and to help clarify and prioritise research agendas and policy recommendations to maximise impact.

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ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
K12	Primary and secondary education ("kindergarten to 12th grade")
TRL	Technology Readiness Level
VR	Virtual Reality

1 INTRODUCTION

DEL4ALL aims to coordinate stakeholders and developments across Europe in the sphere of Digital Education, with the objective of promoting collaboration, best practice, and resilience. In order to analyse the technological and educational activities identified by the project, it is important to identify where activities and actors sit in the landscape of digital education. The DEL4ALL Technology vs. Education Matrix aims to support the mapping of that landscape. Over the course of the project, it will be used to cluster activities, actors, use cases and best practice, to identify synergies and complementary developments, and to determine where (and why) there are gaps in the ongoing efforts. The analysis of activities will then also be used to refine the Matrix and the model underlying it.

The concept is to identify technologies and learning contexts, and to identify actors and activities which connect technologies to contexts, either in application, expertise, or interest. This approach offers a flexible means of analysis with regard to pedagogical and technological aspects. By considering how particular technologies (e.g., blockchain, AI, augmented or virtual reality) and technological features (e.g., decentralised, or interactive) related to different aspects of a learning context (e.g., type of learner/educator/institution, pedagogical framework), we can identify solutions and gaps, as well as best practices and challenges. In particular, by relating the requirements and affordances of technologies and learning contexts, we can also determine where digital education activities display resilience.

This deliverable sets out the initial structure for crowdsourced data collection for the Technology vs. Education Matrix, with the methodology used to create, represent, and refine it.

1.1 SCOPE AND USE

The scope of this document is to describe a data model for the Technology vs. Education Matrix, and the thinking behind it. There are two components whose contents we are collecting during the project. The DEL4ALL catalogue captures data about ongoing activities and relevant actors – specific projects and people in the use of new technologies for digital education. From the collected contents of the catalogue, as well as the digital education literature, we then construct the Matrix. For example, where the catalogue may describe details and contexts of use of the QualiChain and Blockchain for Education projects, each of which deal with verifiable certification of learning outcomes, the Matrix would relate the technology of blockchain-verified certification in general to the appropriate learning contexts in which it is used overall.

Versions of the Matrix are intended to serve as the basis for analysis of the digital education landscape, to inform the work of the rest of the DEL4ALL project.

1.2 DEL4ALL PRINCIPLES FOR EDUCATION

Education is lifelong and must be inclusive and effective. The COVID-19 pandemic has highlighted these points in a number of ways. While the difficulties in moving to online education for professional teachers and institutions have been clear, it has also been necessary for those who are not professional educators, from all kinds of background and in all kinds of context, to take on some teaching activities themselves – parents, neighbours, content producers, and so on – which in turn requires further learning on their part. And in all cases, it has been important to reflect on teaching well in difficult circumstances.

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It is a fundamental assumption of the project that tools for digital education have the potential to support these principles. In particular, a learner-focused digital education landscape, with appropriate pedagogical principles first, is needed to provide inclusivity and effectiveness. Decentralisation supports flexibility across different contexts and requirements, therefore also bolstering inclusivity and supporting learning throughout life. We argue that such an approach to digital education supports the crucial notion of resilience.

In developing the Technology vs. Education Matrix, and the model behind it, we take as a starting point the notion of "educational context", and" and consider pedagogy and technology as they relate to the various aspects of such a context. A decentralised and resilient model of lifelong learning can be constructed by considering best practices in transferring educational technology effectively across contexts.

1.3 METHODOLOGY

The model beneath the Matrix must of necessity be a living model; digital education is a fluid landscape, particularly at the time of writing when face-to-face education globally is made impossible due to the COVID-19 pandemic. We can say from the outset that factors such as technology type and readiness level, pedagogical context and intended audience are important, but, as digital education activities are identified and classified "in the wild", it is to be expected that we will develop new understandings of what is relevant to supporting them, and what new contexts and approaches are emerging. The model proposed here cannot therefore be static, and will be revised throughout the duration of the project in an iterative and incremental process.

The overall method is to identify a first model based on the project goals, and a small number of "seed" activities and actors, and to develop a workflow for classifying new ones identified during the project, refining the model where necessary, in order to support clustering of related topics and collating use cases and best practices. The model will be represented in a very lightweight semantic framework, supporting convenient integration of related data.

We describe in the following section the (initial version of the) data model used for the Matrix, as largely identified in a top-down approach from the project goals, based on a definition of learning context and relating technology to contexts and to the relevant entities (representing activities/projects and experts/groups).

The primary effort in refining the model, populating the catalogue of activities and experts, and deriving the contents of the Matrix will be generated from crowdsourcing from experts and stakeholders across Europe. By collecting self-reported profiles of current activities and expertise, and areas of application, from experts, we will be able to identify common themes and issues, and add or refine relevant dimensions and sets of values to the model, improving its ability to represent the space of digital education in Europe.

1.3.1 Terminology

For the sake of clarity and interoperability, we aim to use standardised terminology wherever possible for terms relating to education. These will be drawn, where possible, from public terminologies, such the CEDEFOP terminology [2] for education and training, the Computer Science Ontology [4], or the Digital Learning Glossary from the Wisconsin Department of Public Instruction [5]. Where appropriate terms do not exist in these terminologies, we choose new terms appropriate to the focus of DEL4ALL.

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2 TECHNOLOGY VS. EDUCATION MODEL

The purpose of the Matrix is to provide a framework for grouping related digital education activities and actors, and enabling the mapping of technologies to educational contexts. The underlying data model is being used to record those activities and actors, initially via online spreadsheet, and later via a dedicated web portal, to form the catalogue. The portal will expose the collected activity data using a lightweight semantic annotation of this model, to maximise interoperability with external sources of relevant data.

2.1 CONCEPTS

2.1.1 Requirements, Affordances and Resilience

Specific technologies, and specific learning contexts, have specific requirements and affordances. That is to say, there are prerequisites relevant to a technology or learning context, as well as potential actions on them. A technology such as VR requires particular hardware, but affords the possibility of interacting in a simulation of a face-to-face environment; a university lecture hall requires that people be able to get to it physically, but affords the possibility of real-time face-to-face interaction.

When considering the transfer of a technological or pedagogical solution from one context to another, then as a minimum, the affordances of the new context must meet the requirements of the solution, and vice versa, or relevant and effective adaptations must be possible (and must be done). Resilient digital education solutions are those capable of being effectively transferred between multiple contexts.

To give an example, a traditional university lecture requires participants to be present simultaneously and affords real-time verbal and visual expression of educational material, with some real-time interaction. A technology such as a video conference has similar features, and therefore can be used to implement a similar pedagogical approach. This does not imply similar levels of effectiveness, merely the possibility of transfer.

2.1.2 Learning Context

"Learning context" is a complex concept, with a number of elements. Broadly, we take it to mean a setting in which (digital) education takes place. More concretely, we can interpret it as comprising the answers to a set of simple questions:

1. **Where?** The setting or location of education, e.g., in a university, secondary school, home, online, etc.
2. **Who?**
   a. Who is learning?
   b. Who is teaching?
   c. Who is involved in another role (and which role)?
3. **What?** The activity taking place, e.g., content creation, content delivery, assessment, etc.
4. **How?** The pedagogical framework or learning design employed, e.g., learning by doing, project-based learning, etc.

For completeness, we could also add the goals of stakeholders (the "why?") and the time of learning ("when?"). However, practically speaking, the goals for learning and education are highly

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variable even within a context, and largely inaccessible to outside the context, and, beyond the distinction between synchronous and asynchronous participation in learning, time is closely related to the setting.

A task for the analysis of particular learning context data, as it is acquired over the course of the project, is to determine the requirements and affordances of each.

2.1.3 Technology

The families of technology types initially focused in the project will be drawn from those identified in the proposal and project kick-off – blockchain, artificial intelligence (symbolic and machine learning), and augmented and virtual reality. These will serve as 'seeds' for populating the Matrix with further types identified as the project progresses.

As discussed above, technology often has specific features - requirements or affordances - and these, in conjunction with those of learning contexts, can inform about the potential to transfer technologies from one context to another, and contribute to the interpretation of resilience. By recording both requirements and affordances, we enable the clustering of technologies by application to different contexts, either better to identify features which are particularly beneficial (or otherwise) for certain pedagogical uses, or to identify where (for example) there may be productive or exploitable gaps in the current space of activities.

Technology readiness level is, of course, highly significant for determining the timescales and likelihood of impact of a technology on digital education.

2.1.4 Activities and Experts

The relationship between a particular learning context and a particular technology becomes concrete where there is some entity connecting them. In particular, in the context of DEL4ALL, we consider the application of a technology to a learning context, and expertise or interest in the combination of a technology and learning context.

We therefore need to represent such connecting entities in terms of either *activities* or *actors*, as appropriate.

2.2 MODEL

In order to crowdsource the contents of the Matrix, the concepts above need to be turned into a data model describing the specific attributes to be collected for each concept. In general, of course, not every attribute will be relevant for everything for which data is collected.

2.2.1 Technology

TABLE 1 DATA MODEL: TECHNOLOGY ATTRIBUTES

Attribute	Example
Name	
Technology type	e.g. Blockchain, AI, etc.

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Technological features	e.g. Decentralised, Interactive, etc.
Technology Readiness Level (TRL)	In the range of 1-9

Technological features are intended to record the relevant requirements and affordances of the technology in question.

2.2.2 Learning Context

TABLE 2 DATA MODEL: LEARNING CONTEXT ATTRIBUTES

Attribute		Examples
Learning setting		Institution, citizen science, home, …
Learning Activity		Content creation, learning delivery, certification, …
Pedagogical framework		Personalised, inquiry-based, …
Learning context features		Interactive, asynchronous, …
Stakeholders		
	Learner type	Children, adult full-time, …
	Teacher type	Formal, informal, self, ..
	Other Actor types	Institution, government, …

Learning Activity is specifically intended to represent the main process(es) of education involved. We anticipate that this has a comparatively small list of possible values. Our initial proposal is as follows (subject, of course, to updates or additions as data is acquired through crowdsourcing):

1. Education policy
2. Learning design
3. Content creation
4. Content publication
5. Learning path creation/selection
6. Learning delivery
7. Formative assessment
8. Summative assessment
9. Pastoral care
10. Guidance and counselling/information, advice and guidance (IAG)
11. Certification of learning outcomes
12. Learning analytics and evaluation

Potential values for the (open-ended) Pedagogical Framework are given in the Appendix. Learning context features, as with technology features, relate to relevant requirements and affordances.

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2.2.3 Entities

There are at least two types of entity to be modelled, which we label activity and actor. Entities have some core attributes.

TABLE 3 DATA MODEL: ENTITY (COMMON) ATTRIBUTES

Attribute	Example
Name	
Description	
Institution	
Institution type	
Webpage	

Activities and actors all inherit the attributes of an entity.

2.2.3.1 Activity

An *activity* represents a project or initiative in the digital education space: a research or commercial project, university/school/regional activity, etc. Activities in particular may be associated (or claimed to be associated) with particular benefits in either technological or educational dimensions, or particular challenges, and evidence (e.g., links to papers detailing studies in efficacy, or evidence for wide-scale use) for both. The attributes specifically for an activity are as follows:

TABLE 4 DATA MODEL: ACTIVITY ENTITY ATTRIBUTES

Attribute	Example
Start Date	
End Date	
Comments	
Technologies	
	Benefits
	Challenges
Learning Contexts	
	Benefits
	Challenges

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2.2.3.2 Actor

An *actor* represents a stakeholder in the digital education space: an individual, group, or organisation active as an expert, producer, consumer of digital education. The attributes specifically for an actor are as follows:

TABLE 5 DATA MODEL: ACTOR ENTITY ATTRIBUTES

Attribute	Example
Role	e.g. researcher, educator, policymaker
Contact details	
Areas of expertise	
Technologies	
Learning Contexts	

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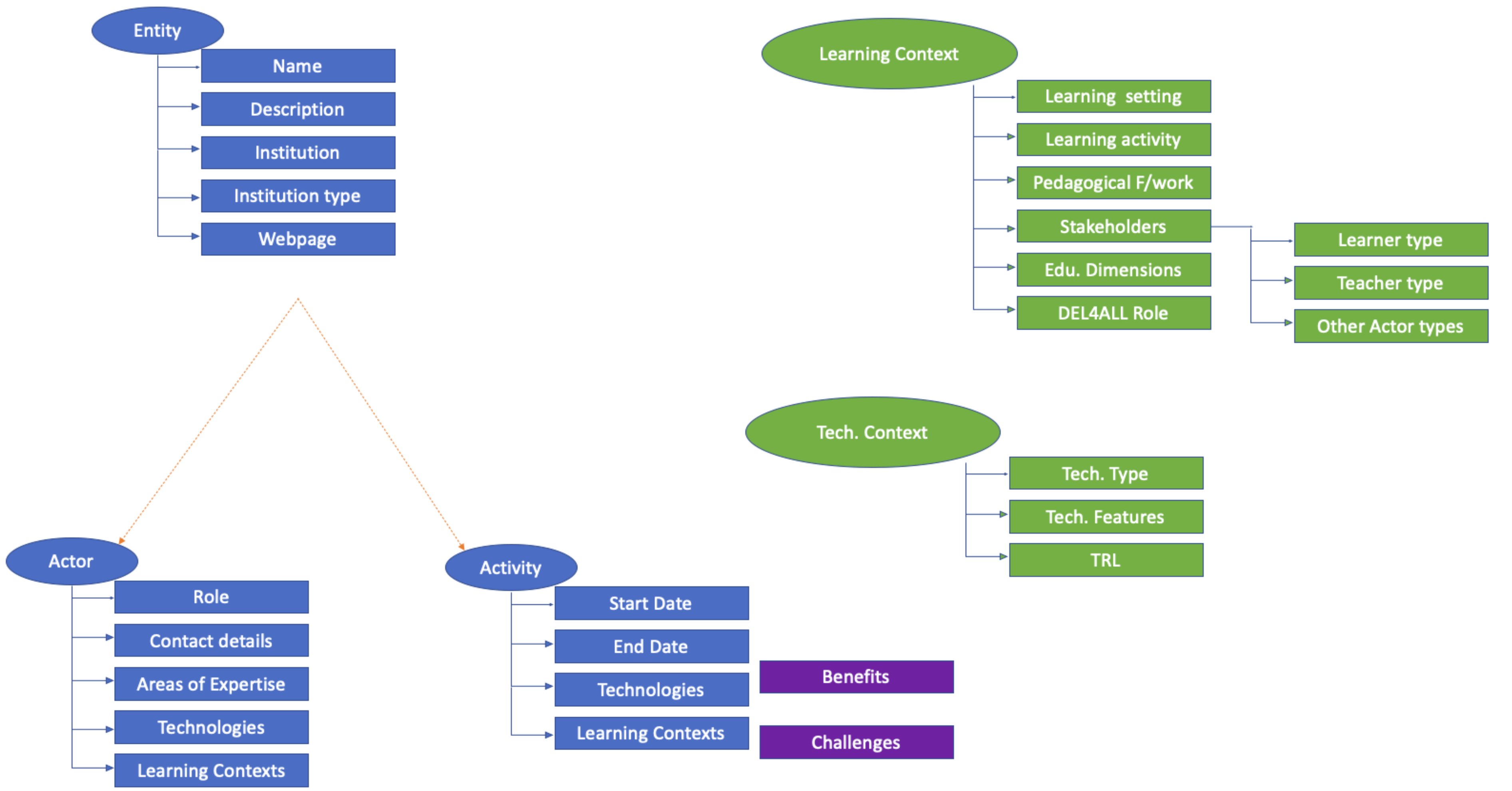

FIGURE 1 INITIAL MODEL FOR TECH. VS. EDUCATION MATRIX

2.3 EXAMPLE

Each of the following subsections contains a tabular representation of data describing some example activities and actors, and the associated learning contexts and technologies, based on work in which project partners are involved. They each correspond to a form or spreadsheet into which crowdsourcing participants could enter data. Technologies and learning contexts are cross-referenced between the tables – collectively, they describe a set of initiatives and experts. For legibility, certain attributes have been merged into one column, or omitted where there is no variation in the example data. (In particular, the actors shown here all have expertise which can be applied to any pedagogical framework, so that attribute has been omitted from the Actors table.)

2.3.1 Activity

TABLE 6 EXAMPLE DATA COLLECTION TABLE FOR "ACTIVITY"

Name	Description	Institution	Institution type	URLs	Start Date	End Date	Benefits & challenges	Technology name	Learning Context[1]
OU SK299 AR Human Heart	Human for SK200 OU course	OU	University				Improved engagement, ease of understanding	AR/VR simulation of physical entities	1
OU E117 AR Human musculo-skeletal system	Human musculo-skeletal system for OU course E117	OU	University				Improved engagement, ease of understanding	AR/VR simulation of physical entities	1
QualiChain	A platform for issuing, sharing, and verification of	QualiChain	H2020 project	https://qualichain-project.eu			Trustable decentralised verification of qualifications in a	Blockchain certification	2

1 See section 2.3.2

	educational credentials using OpenBadges						privacy-preserving system compatible with other Semantic Web data sources		
Blockchain for Education	The Blockchain for Education platform is a secure and intuitive solution for issuing, sharing, and validating of certificates	FIT	Research institute	https://www.fit.fraunhofer.de/en/fb/cscw/projects/blockchain-for-education.html	1st Nov 2017		Higher efficiency and improved security for certification authorities through digitization of current processes, issuing and tamper-proof archiving of digital certificates in a blockchain as well as automatic monitoring of certificates	Blockchain certification	2
EBSI Diplomas group	Standardisation initiative for blockchain certification							Blockchain certification	2

2.3.2 Actor

TABLE 7 EXAMPLE DATA COLLECTION TABLE FOR "ACTOR"

Name	Description	Institution & type	Webpage	Role	Areas of Expertise	Learning setting	Learning activity	Stakeholder type(s)	Other Actor type(s)	Learning Context
Alex Grech	Architect of nation state blockchain credentials project. Advisor	3CL		Higher education teacher,	Digital Literacies, New Media, Social Sciences,	Any formal education	Education policy, Content creation, Certification	Learner: Adult	Policymakers, Companies, Education foundations	3

	to Minister for Education & Employment in Malta (now Minister for Foreign Affairs). Looking at developing digital education platforms for African teachers.			Researcher	Educational platforms		of learning outcomes			
Sabine Kolvenbach		Fraunhofer FIT, Research institute		Researcher		Any formally-certified education	Certification of learning outcomes		Companies, Educational institutions	2

2.3.3 Learning Context

TABLE 8 EXAMPLE DATA COLLECTION TABLE FOR "LEARNING CONTEXT"

	Learning setting	Learning activity	Pedagogical framework	Learner type(s)	Teacher type(s)	Other Actor type(s)
1	Distance higher education	Learning delivery	Blended learning	Adult	Higher education tutor	
2	Any formally-certified education	Certification of learning outcomes		Adult		Educational institutions, universities, certification authorities, companies.
3	Any formal education	Education policy, Content creation,		Adult		Policymakers, companies, education foundations

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		Certification of learning outcomes				

2.3.4 Technology

TABLE 9 EXAMPLE DATA COLLECTION TABLE FOR "TECHNOLOGY"

Technology name	Technology type	Technological features	Technology TRL
AR/VR simulation of physical entities	AR/VR	Simulation, Specialist hardware	
Blockchain certification	Blockchain	Decentralised,Verifiable	7

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3 TECHNOLOGY VS EDUCATION MATRIX

Given a data model and appropriate data capture services, the online catalogue of activities and actors can be populated to provide a data-driven basis for the Matrix, ensuring that it accurately represents the current landscape, and therefore validating subsequent analyses performed with it. The crowdsourcing of this data will feed into future versions of the Matrix.

To illustrate the Matrix in the absence of large-scale crowdsourced data, multiple sources of documentary information were used, in order to produce an initial version to begin work with. Specifically, the table below was derived from

- Preliminary analysis described in the DEL4ALL Document of Action
- The list of invited candidates for the DEL4ALL Advisory Board, and their interests and activities
- The initial list of experts identified as DEL4ALL stakeholders, and their interests and activities,
- A selection of review papers on educational technology ([1], [3]), and
- Expertise among consortium members.

TABLE 10 TECHNOLOGY VS EDUCATION MATRIX

Tech.	Example	Tech. Feature	Learning Setting	Learning Activity	Pedagogical framework	Stakeholders	Stakeholder Details	Benefits	Challenges
AR/VR	VR laboratory	Interactive multimedia	Higher education, secondary education, online education	Practical coursework		Learner, Teacher, Content Creator	Adult & child learners in formal & informal contexts	Pedagogical: remote access to facilities	Technological: Access to/cost of hardware
AI	Course recomme ndation	Machine-learning recommendati on	Formal	Course selection		Learner, Content Creator	Formal learners, formal content creators	Pedagogical: better matching of learners to courses, easier discovery of courses, potential widening of participation	Pedagogical: algorithmic bias; Technological: data sources
AI	Job recomme ndation	Machine-learning recommendati on				Learner, Employer		Pedagogical: better matching of people to jobs, easier discovery of jobs/candidates, potential widening of participation	Pedagogical: algorithmic bias; Technological: data sources, matching skills to recruitment
AI	Curriculu m personalis ation	Machine-learning recommendati on	Formal	Content delivery	Online and blended learning	Learner, Teacher, Institution	Online/blende d learners, online/blended teachers	Pedagogical: personally-created learning pathways, learner mobility, connectivity between institutions, more effective use of limited resources	Pedagogical: variability in meaning of credentials; Technological: data sources

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AI	Content adaptation	Natural language generation		Content creation		Content Creator, Institution		Pedagogical: context-tailored content, more inclusive materials, more efficient use of limited resources	Technological: quality and user experience, data sources
AI	Automation of human conversation	Natural language generation	Online	Content delivery	Online and blended learning	Learner, Content Creator	Online/blended learners, online/blended teachers	Pedagogical: more effective use of limited resources, any-time access to learning materials	Technological: quality and user experience
AI	Learning analytics	Machine-learning classification		Content delivery, learner support		Learner, Teacher, Institution		Pedagogical: better targeting of support, accommodating diverse needs, content delivery improvement, learning path improvement	Technological: privacy/data protection, scalability

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Blockchain	Qualification verification	Tamper-proof data		Credentials		Learner, Institution, Employer		Pedagogical: verifiable accreditation for wider/more fine-grained learning contexts (e.g., microcredentials), potential widening of participation, student mobility, reduction of fraud; Technological: rapid trustworthy verification, decentralisation, lower cost of validation, increased transparency	Technological: privacy/data protection, scalability
Blockchain	Learning portfolio verification	Tamper-proof data		Credentials		Learner, Employer		Pedagogical: wider opportunities to demonstrate achievements, reduction of fraud; Technological: rapid trustworthy verification, decentralisation, lower cost of validation, increased transparency	Technological: privacy/data protection, scalability, lower hiring costs
Blockchain	Reward for educational content	Trustable asset transfer		Content creation		Content Creator		Pedagogical: lower barriers to entry, widening participation in content creation, fair reward for efforts,	Technological: scalability

	creation/adaptation							encourages innovation, encourages reuse of best practice; Technological: increased transparency	
Games	Educational games	Gamification of learning		Content delivery	Inquiry-based learning	Learner, Content Creator		Pedagogical: widens scope of inquiry-based learning online, any-time access to learning materials, less human teaching effort	

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4 CONCLUSION AND FUTURE STEPS

We have presented the first version of the data model for the DEL4ALL Technology vs. Education Matrix, and an initial version of the Matrix itself. The primary source for a grounded and detailed Matrix is a detailed catalogue of activities and actors in the area of digital education, and the data model here will provide a structured basis for collecting the information to populate the catalogue. Such information in turn will feed into analyses of the digital education landscape needed to refine and expand the Matrix, and to support the work of DEL4ALL in promoting resilience in education across Europe, which is a particular priority at the time of writing and is likely to remain so going forward.

As discussed earlier, the question of resilience, always important, has been highlighted globally by the COVID-19 pandemic, in particular by the very short term need for very large numbers of learners and educators to transition to new contexts for learning. The outcomes of, and public conversations about, this transition have been dominated by the practical and pedagogical difficulties, and the availability of information about each.

The pedagogical approaches in online learning are not simply transferred versions of face-to-face pedagogies, and the possibilities online do not match one-to-one with the physical. By making learning context, and the elements which make that up, the heart of our modelling and analysis, and recording and analysing technological and pedagogical requirements and affordances, we enable the future construction of a map between approaches to education and the contexts in which they have been, and, more importantly, could be, applied. The design of the model presented here is intended to support the identification of resilient practice, to enable us to direct attention to the technologies, pedagogies, and the smartest uses of both, to provide better support for digital education in the current crisis, and in the future.

In order to be as effective as possible, we are developing data collection workflows, initially based on online spreadsheets, with a dedicated portal in progress, which will support experts and DEL4ALL stakeholders in entering, analysing, and aggregating data, and will provide different means of visualisation. The latter in particular is intended to make the contents of the multidimensional catalogue and Matrix accessible in more flexible ways than can be achieved in a two-dimensional PDF. Perhaps more importantly, the social aspects of crowdsourcing data such as this will be expanded upon in WPs 2 and 3 (DEL4ALL COMMUNITY and GUIDE, respectively), to make the best use of the planned workshops and other consultation tools, and to ensure that participation and contribution of data is mutually beneficial for all stakeholders. Work throughout the project in terms of outputs, such as research prioritisation and policy recommendations, will also feed back into the data model and Matrix, ensuring a beneficial cycle of refinement, analysis, and output throughout.

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APPENDIX: TERMINOLOGY EXAMPLES

Various elements of the data model have open-ended potential values where it would be useful for analysis purposes to draw terms from standard vocabularies. We give here simply some examples of terms for these attributes. These are by no means intended to be exhaustive; it would be harmful to limit the scope of values here. It is to be expected that we will encounter initiatives where no standard terms are entirely appropriate; we intend to collate any such terms and publish them as outputs of the project.

Technological features

- Asynchronous
- Synchronous
- Collaborative
- Gamification
- Interactive
- Decentralised
- Private
- Simulation
- Specialised (or widely-available) hardware
- Computationally intensive

Learning context features

- Asynchronous
- Synchronous
- Collaborative
- Interactive
- Private
- Face-to-face

Pedagogical Frameworks

- Adaptive Learning
- Asynchronous Learning
- Synchronous Learning
- Distance learning
- Blended Learning
- Cooperative Learning
- Game-based Learning
- Personalized Learning
- Social Learning

Learning settings

- Formal
  - Higher education
  - Secondary education
  - Primary education
  - K12 education
  - Corporate training/Continuing PoD
- Informal
  - Self-study
  - Citizen science
  - Public education events
- Non-formal
  - On-the-job training
  - Passive learning

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