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Abstract	One of the objectives of DEL4ALL is to identify the ways in which different technologies are being used in education. We present here an analysis of the learning projects identified using the DEL4ALL Technology vs. Education Matrix and the information on experts and projects identified by DEL4ALL so far. The results are used to draw some conclusions about the current state of the educational technology landscape, as well as to

	provide a visual lens to inform the use of the DEL4ALL online catalogue as a portfolio of learning projects.
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** 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.

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EXECUTIVE SUMMARY

The principal goal of DEL4ALL is to coordinate between stakeholders and developments across Europe, promoting collaboration, best practice, and resilience in digital education. The project explores technologies that play a crucial role in education as they can enhance learning capability or provide alternative approaches easing challenges and difficulties that might otherwise act as obstacles. One of the objectives of this project is to identify the ways in which different technologies are being used in education. We present here an analysis of the learning projects identified using the DEL4ALL Technology vs. Education Matrix and the information on experts and projects identified by DEL4ALL so far.

We consider the impact of technologies in terms of their *scale*, *diversity*, and *maturity*, using metrics for each derived from the DEL4ALL experts and projects data, and, where relevant, broken down by associated learning activity and type of stakeholder.

The results indicate that the most active educational technologies represented in the DEL4ALL portfolio are concerned with established technologies such as digital education platforms, or widely known but "backroom" technologies such as AI and Machine Learning. Advanced technologies such as blockchains, IoT, or those whose adoption would involve significant learner-facing adaptations appear to receive less development attention. We conclude that this may indicate further attention needs to be paid to pathways from research to educational practice.

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ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
IoT	Internet of Things
VR	Virtual Reality

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1 INTRODUCTION

The principal goal of DEL4ALL is to coordinate between stakeholders and developments across Europe, promoting collaboration, best practice, and resilience in digital education. The project explores technologies that play a crucial role in education as they can enhance learning capability or provide alternative approaches easing challenges and difficulties that might otherwise act as obstacles. One of the objectives of this project is to identify the ways in which different technologies are being used in education. We present here an analysis of the learning projects identified using the DEL4ALL Technology vs. Education Matrix and the information on experts and projects identified by DEL4ALL so far. The results are used to draw some conclusions about the current state of the educational technology landscape, as well as to provide a visual lens to inform the use of the DEL4ALL online catalogue as a portfolio of learning projects.

1.1 SCOPE

The scope of this document is to describe the learning projects portfolio developed by analysis of the existing entries in the aggregator and the Technology vs. Education Matrix version 2.0.

1.2 METHODOLOGY

Over the previous year, the DEL4ALL project has extracted this information from experts, industry leaders and practitioners. The mapping of technologies and learning context with more than four hundred activities, stakeholders, and experts identified in the past year provides the portfolio's underlying foundation.

The catalogues collecting information for activities and experts in the DEL space are the primary sources for building the portfolio, along with the DEL4ALL Technology vs Education Matrix, together providing the basis for identifying the clusters of similar projects and their activities. The clusters are formed based on technology and the nature of the service each initiative provides. As the current version of the aggregator captured a single technology against each initiative, they are first sorted by representative technologies. Each initiative identified by a specific technology is then compared with their peers to identify similarities between the services they provide. For example, after breaking down initiatives under blockchain technology, some initiatives are found to offer verification functionalities while some provide decentralised identity or platforms. Therefore, three clusters, namely qualification verification, decentralised identity and decentralised platform, are formed corresponding to blockchain technology. The same method is followed to create clusters for other technologies.

We primarily consider the results broken down by Technology, with the raw number of entries per category as a measure of the *scale* of activity with that technology, and the number of clusters per category as a measure of the *diversity* of activity with that technology. We then consider clusters as they apply to Learning Activity and

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Stakeholder type. We also, separately, chart the scale of activity broken down by the type of organisation involved, as a means of identifying the maturity of that activity.

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2 TECHNOLOGIES

The learning portfolio utilises various technologies that are grouped within nine large classes. The classes include Artificial Intelligence, Augmented Reality, Big Data, Blockchain Technology, Digital Education, Game, Internet of Things, Machine Learning and Virtual Reality.

2.1 ARTIFICIAL INTELLIGENCE (AI)

Artificial intelligence is intelligence expressed by programs or machines. However, it is different from human and animal intelligence that is natural and mixed with emotions; hence, the qualifier 'Artificial'. Amongst the technologies, we classed Machine Learning separately, although that is also a kind of artificial intelligence.

AI is used in various ways in the learning and educational domain. Natural language processing, AI-aided learning experiences, and AI-based interface design are a few to name where artificial intelligence which is not derived from machine learning is used.

2.2 AUGMENTED REALITY (AR)

Augmented reality (AR) is an interactive encounter with a real-world environment where the real objects are magnified or improved by computer-generated perceptual information, sometimes across multiple sensory modalities: visual, auditory, haptic, somatosensory, or olfactory. AR is often discussed with Virtual Reality, but they are different in nature and as technology. For example, AR can be experienced using a standard smartphone, with no need for special goggles. Therefore, we classed them separately.

AR can help enhance learning experience and create online-based laboratories and examples while providing teaching.

2.3 BIG DATA

Big data is a discipline to analyse or systematically extract information data sets that are too large or complex to be dealt with by standard computing facilities. Big Data offers greater statistical power, although higher complexity could lead to a higher false discovery rate. It was initially associated with three key concepts: volume, variety, and velocity, but later other attributes have been introduced in it.

Big data helps us to understand the learning and education domain by, e.g., analysing learners' interactions and data. Along with machine learning, it offers smart learning experiences, while teachers can benefit from receiving automated instructions and feedback from the system.

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2.4 BLOCKCHAIN

Blockchain is a recording system designed to guarantee the integrity of records without a need for a centrally trusted authority. It is essentially a digital ledger of transactions that is duplicated and distributed across an entire network connected in a peer-to-peer form. Crucially, a blockchain is built by consensus, and uses cryptographic techniques to make it prohibitively expensive, and to require majority consensus, to edit previous records – effectively making blockchains immutable.

Blockchain technology plays an important role in the education and learning domain by offering tamperproof decentralised certification, smart CVs, job matching and so on. More recently blockchain has also been used to develop smart curricular and feedback management system for teachers and students.

2.5 DIGITAL EDUCATION PLATFORMS

Digital education platforms include the innovative use of digital tools and technologies specifically to support teaching and learning activities in themselves, and is often referred to as Technology Enhanced Learning (TEL) or e-Learning. Exploring the usage of digital technologies allows educators to incorporate engaging learning opportunities in the courses they teach. These can take the form of blended or fully online courses and programmes in a digital environment.

2.6 GAMES

Games (specifically, video games) are activities in which technology is applied to encourage or implement play. Games offer many ways to improve and enhance learning experiences online and in physical classrooms.

2.7 MACHINE LEARNING

Machine learning is the method of implementing software for making accurate predictions when fed data. Predictions could be identifying whether a piece of fruit in a photo is a banana or an apple, or spotting people crossing the road in front of a self-driving car. Other types of prediction could be identifying whether a use of the word "book" in a sentence is related to a paperback or a hotel reservation, whether an email is spam, or recognizing speech accurately enough to generate captions for a YouTube video. The key difference from conventional computer software is that a human developer has not written code that instructs the system how to tell the difference between the banana and the apple. Instead, the machine-learning model is taught to reliably discriminate between fruits by being trained on a large amount of data. In this instance, a considerable number of images containing bananas or apples would be tagged appropriately for the software to learn from.

Machine learning is one of the most popular technologies that is heavily used in the education and learning domain: online learning platforms, teaching, data management, scheduling and assisting students with learning — everywhere it can play a part.

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2.8 VIRTUAL REALITY (VR)

Virtual reality (VR) is a simulated experience designed to feel real and immersive to users. Applications of virtual reality include entertainment, skill development and education. It helps users to practise driving cars, performing medical operations, undertaking military training and so on. In education, it helps to create virtual laboratories, libraries, classrooms, etc.

2.9 IOT

The Internet of things (IoT) represents the network of electrical objects ("things") that are installed with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet. It helps, for example, to create virtual laboratories by providing streams of real data while also enhancing a classroom's learning experience.

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3 LEARNING ACTIVITY, STAKEHOLDERS AND TYPES OF INITIATIVES

While technology plays an influential role in enhancing learning activities and motivating stakeholders, the types of organisations that are involved in those activities show how those technologies are adopted at various levels in the industry. In this deliverable, we aimed to observe the impact of technology on the DEL space with respect to learning activities, stakeholders and types of initiatives that produce those activities.

3.1 LEARNING ACTIVITY

A learning activity is an activity designed or deployed by a teacher to create learning conditions. Some learning activities stimulate experiential learning, while others encourage students to engage in analytical discussion. The following five learning activities have been identified amongst the initiatives for impact analysis.

Content creation is the process of creating material to be used for education. When it comes to educational content creation, the activity involves creating classroom-based or online contents that students can access by attending a face-to-face class or visiting a website.

Content delivery is arguably the most common learning activity in the DEL space. It can be classroom-based, online or blended. Teachers teaching in the classroom, a recorded lecture presented on online platforms, education activities such as laboratory experiments and skill development, and so on, are amongst the most prominent content delivery examples.

Data management and analysis for teaching and learning data, student records and qualification information management can be applied across multiple aspects and processes of education – for example, managing and analysing data to make decisions that help with curriculum design and teaching provision. This category combines, for ease of analysis, Learning Path Creation, and Learning Analytics and Evaluation, which in practice have turned out to have significant overlap with regard to data technologies.

Certification of learning outcomes, or credentials, can be the diploma awarded upon successful completion of a degree or certificates from a university of online institution for a short course. The management of these credentials is also considered to be a part of the learning activity.

Information, advice and guidance activities include recommendations such as course and job recommendations which play important roles by providing learners with help to select suitable courses or apply for appropriate jobs.

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3.2 STAKEHOLDERS

Stakeholders are the entities involved the educational activity, each with their own perspective on activities, and potentially targeted as the audience for them. There are the following stakeholders identified in the collected data and reported in D1.2:

- Content Creators
- Institutions
- Learners
- Educators
- Employers

For Learners and Educators, we distinguish face-to-face and online/blended education.

3.3 TYPES OF INITIATIVE

There is a total of 441 initiatives about which we collected information. These initiatives are further grouped, in the experts and activities dataset, into six types based on their size, operation and nature. These six types are:

- Established
- Infrastructure
- Platform
- Research
- SME
- Start-up

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4 TECHNOLOGY-AIDED LEARNING CLUSTER

By analysing the data collected by the aggregator, we combined similar learning activities together to form 21 clusters of initiatives that offer technology enhanced educational and learning activities. The following table provides with the clusters and their descriptions.

TABLE 1 TECHNOLOGY AIDED LEARNING CLUSTER

Technology	Cluster	Learning Setting	Activities	Claimed Benefits
Artificial Intelligence	Automation of Human conversation	Online	Content delivery	Any-time access to learning materials
	AI-aided Speech improvement	Online	Speech practice	Allows users to improve their accent by reading text in a loud voice, comparing this speech to a speech of a native speaker
	Content Adaptation	Classroom, Online, and Blended	Content creation and teaching materials preparation	Context tailored content, more inclusive materials, more efficient use of limited resources
Augmented Reality	AR-based teaching	Classroom	Holographic lessons	Holographic lessons helps provide a greater depth of access to the tools and information necessary to take away a deeper understanding of any subject matter
Big Data	Big data analysis	N/A	Actionable data-driven insights	Empowers institution-wide improvement through predictive and data-driven insights
Blockchain	Qualification verification	N/A	Tamper-proof decentralised credentials	Rapid trustworthy verification, decentralisation, lower cost of validation, increased transparency
	Decentralised identity	Classroom, Online, and Blended	Decentralised identity management	Provides stakeholders to manage their identities in a

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				decentralised setup with provision for selective disclosure of information
	Decentralized platform	Online	Decentralized educational tool for educators	Enables educators to upload their schedules, classes, and curriculum onto the blockchain
Digital Education Platform	Lifelong Learning Platform	Online	Courses offered on online platforms	Flexible Learning from online courses
	Online platform for teachers	Online	Learning from flexible online courses for teachers	Helps teachers adopt innovative methods of delivering and enhancing a personalized educational experience
	Social and Online safety awareness	Online	Social, educational, health and online safety activities	Flexible learning through activities
	Live Online Community	Online	Live discussions	Learning from discussions and exchanges
	Distance Learning for Special Need Children	Online and Blended	Need-based learning pathways	Online platform, effective use of limited resources
	Collaborative learning	Online	Learning from collaborative discussions	Learning by participating in projects, events and other mutual-learning activities
Game	Educational games	Online	Content delivery	Gamification of learning
IoT	Enabling-technology	Classroom, Online, and Blended	Learning assistance	Learning support to achieve greater goals with devices such as raspberry pi etc.
Machine Learning	Course recommendation	Classroom, Online, and Blended	Course selection	Better matching of learners to courses, easier discovery of courses, potential

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				widening of participation
	Job recommendation	NA	Job discovery	Better matching of people to jobs, easier discovery of jobs
	Curriculum personalisation	Classroom, Online, and Blended	Curriculum design	personally-created learning pathways
	Learning analytics	Classroom, Online, and Blended	Learner support	Better targeting of support, accommodating diverse needs, content delivery improvement
Virtual Reality	VR laboratory	Online and Blended	Interactive multimedia	Remote access to facilities

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5 IMPACT ANALYSIS

The total number of initiatives in the aggregator used for this portfolio is 441 across all technologies. They were grouped into 21 clusters identifying similarities of their use cases. The following analyse the impact of technology on various aspects of learning project portfolio on DEL space.

5.1 TECHNOLOGY

The first analysis is conducted to show the direct impact of technologies on the initiatives and clusters. Because the current version of the aggregator captured only one technology against each initiative, it effectively forms a partition classification. Digital Education Platforms are the subject of the largest number of initiatives with 246; it occupies 56% of the total initiatives shown in Figure 1 and Figure 2 respectively.

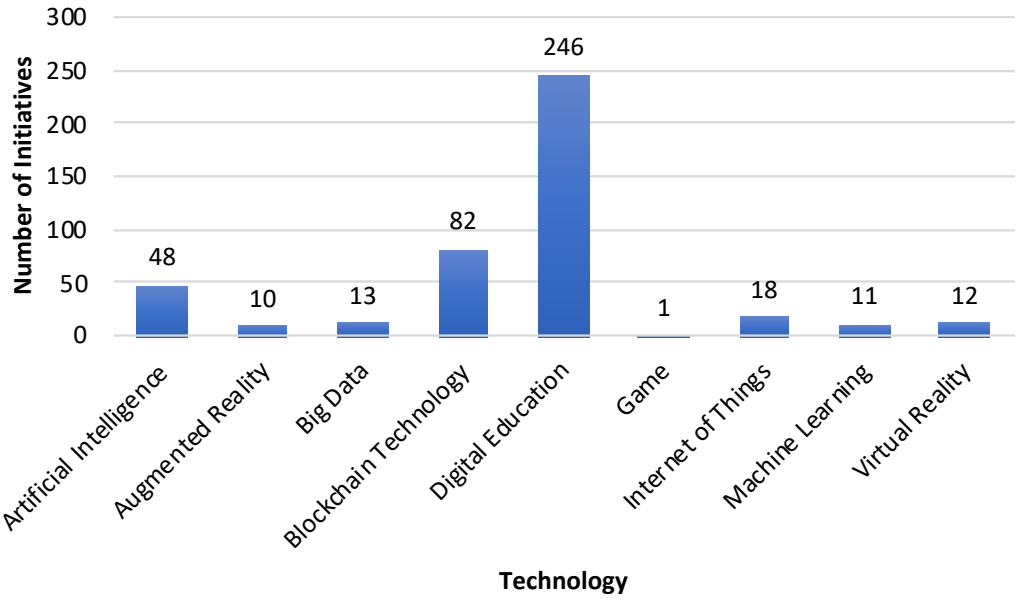

FIGURE 1 TOTAL NUMBER OF INITIATIVES AGAINST TECHNOLOGY

Blockchain Technology provides 19%, Artificial Intelligence 11% and Machine Learning 2%, respectively. It is notable that despite Machine Learning offering only 11 initiatives, it forms four clusters showing the distinctive nature of the use cases. Other technologies are demonstrated by less than 5% of the initiatives each.

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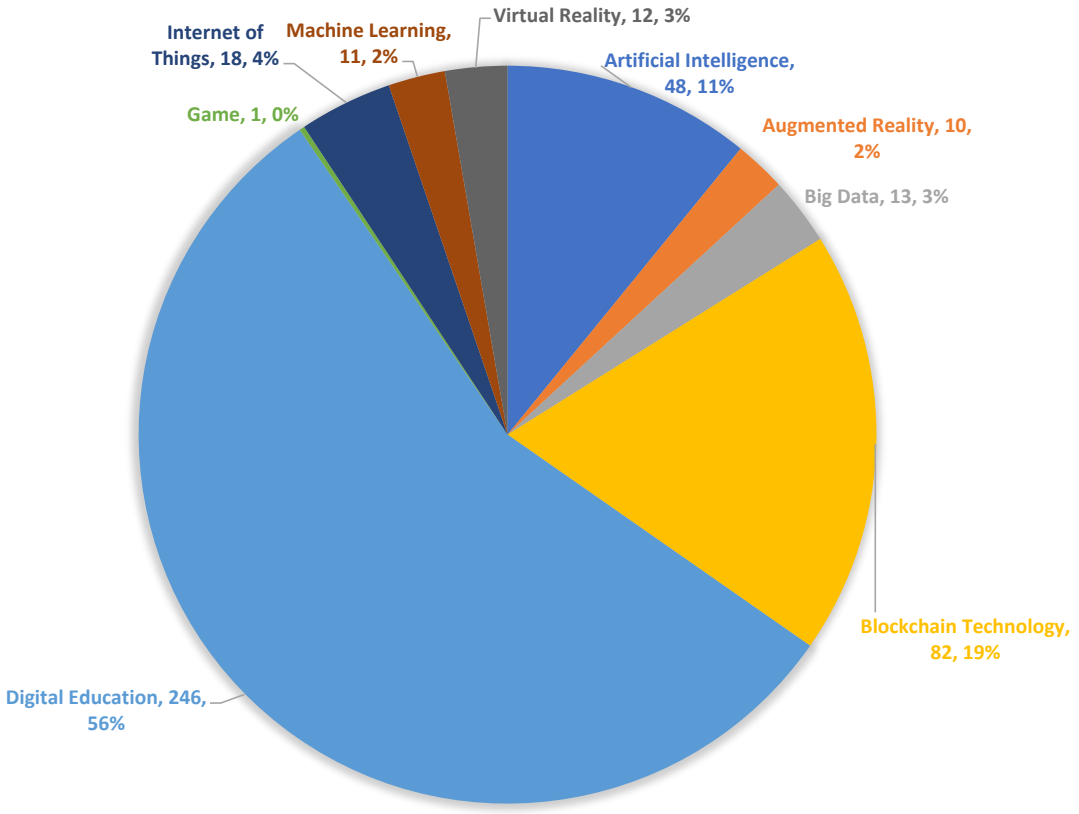

FIGURE 2 PERCENTAGE OF INITIATIVES AGAINST TECHNOLOGY

The nine technologies form 21 clusters of initiatives. Among these, Digital Education Platforms alone forms 6 clusters which is 28% of the total entries. Artificial Intelligence, Blockchain Technology and Machine Learning are other technologies that have three or more clusters. The remaining technologies form a single cluster each, 5% of the entries.

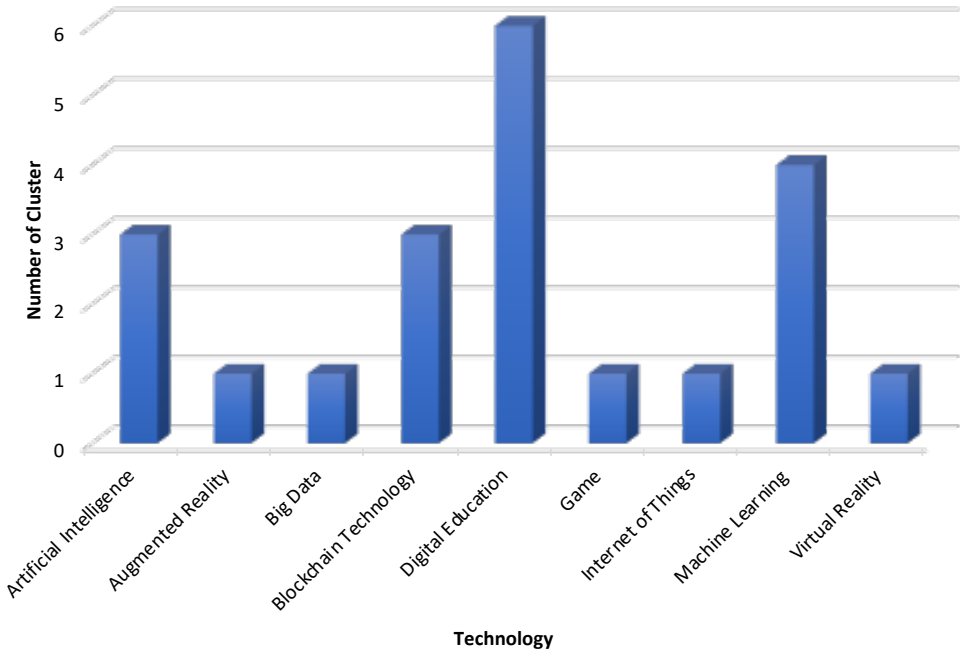

FIGURE 3 TOTAL NUMBER OF CLUSTER BY TECHNOLOGY

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Figure 3 shows the total number of clusters by technology while Figure 4 shows their percentage. It is notable that the largest technology (Digital Education Platform) has more clusters than five of the smallest technologies combined. Although Machine Learning is a subset of Artificial Intelligence, we separated it from the super set to show contributions of the former distinctly. Nevertheless, if we were to consider the clusters they form together, they would outnumber Digital Education Platform clusters. This illustrates the range of different use cases to which various AI technologies are being applied in education.

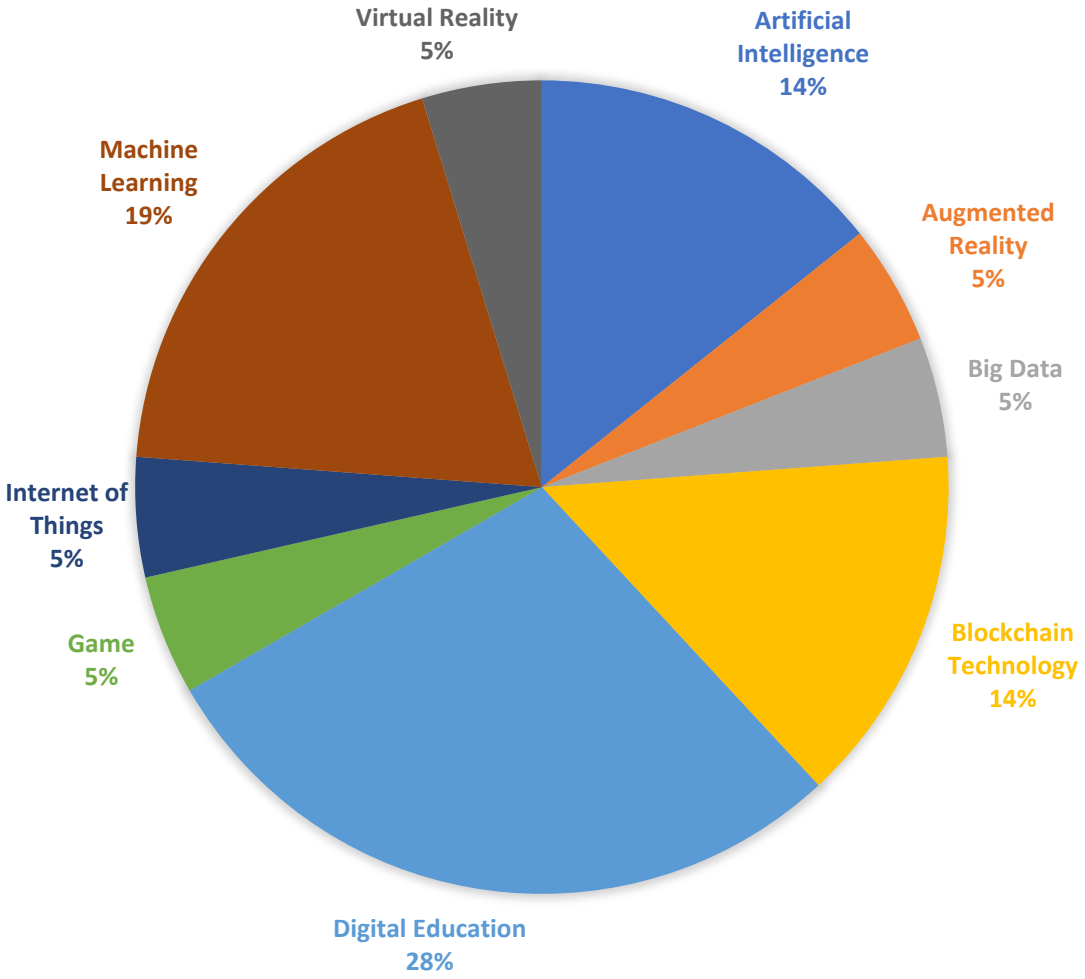

FIGURE 4 PERCENTAGE OF CLUSTER BY TECHNOLOGY

To analyse the diversity better, we further looked at the number of initiatives for each cluster, as shown in Table 2.

Artificial Intelligence has three clusters with a large swing towards content adaptation. 87.5% of initiatives offer some form of content adaptation, while only 6.25% of initiatives provide automation of human conversation and AI-aided speech improvement each. Blockchain technology showed a similar swing towards decentralised platforms with 72% of initiatives offering this service. Only 12% and 16% provide decentralised identity and qualification verification, respectively.

The digital education platform is the technology that captured the largest number of initiatives (246). It also forms the largest number of clusters with six different types amongst the initiatives. Unsurprisingly, lifelong learning platform is the most weighted

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cluster with 77% initiatives providing it. Online platform for teachers is the next largest with 11% initiatives offering some form of facility to help teachers adopt innovative methods of delivering and enhancing a personalised educational experience. About 8% provide live online community while three small clusters of initiatives make up the remaining six per cent.

Machine learning, however, shows an even distribution of use-cases where there is no clear winner amongst the clusters. About 36.5% of initiatives offer curriculum personalisation, while 27.5% provide course recommendation services. About 18% of initiatives offer job recommendations and learning analytics. The remaining technologies form only a single cluster providing the same type of services or applications.

Figure 5, Figure 6, Figure 7, and Figure 8 visualise the clusters within those technology areas with more than one cluster.

TABLE 2 DIVERSITY OF THE CLUSTERS

Technology	Cluster	# of Initiatives	% of initiatives
Artificial Intelligence	Automation of Human conversation	3	6.25%
	AI-aided Speech improvement	3	6.25%
	Content Adaptation	42	87.5%
Augmented Reality	AR-based teaching	10	100%
Big Data	Big data analysis	13	100%
Blockchain	Qualification verification	13	16%
	Decentralised identity	10	12%
	Decentralized platform	59	72%
Digital Education Platform	Lifelong Learning Platform	189	77%
	Online platform for teachers	27	11%
	Social and Online safety awareness	2	0.5%

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	Live Online Community	19	8%
	Distance Learning for Special Need Children	2	0.5%
	Collaborative learning	7	3%
Game	Educational games	1	100%
IoT	Enabling-technology	18	100%
Machine Learning	Course recommendation	3	27.5%
	Job recommendation	2	18%
	Curriculum personalisation	4	36.5%
	Learning analytics	2	18%
Virtual Reality	VR laboratory	12	100%

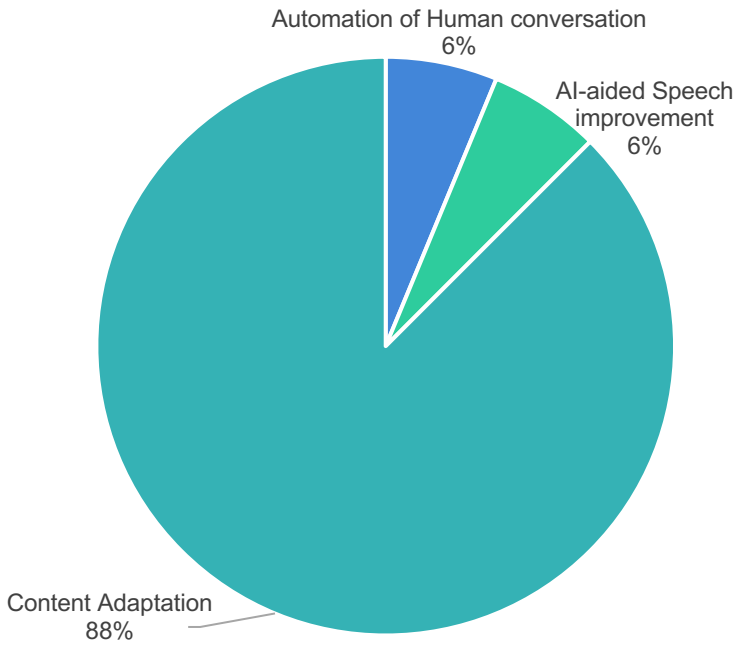

FIGURE 5 CLUSTERS USING ARTIFICIAL INTELLIGENCE

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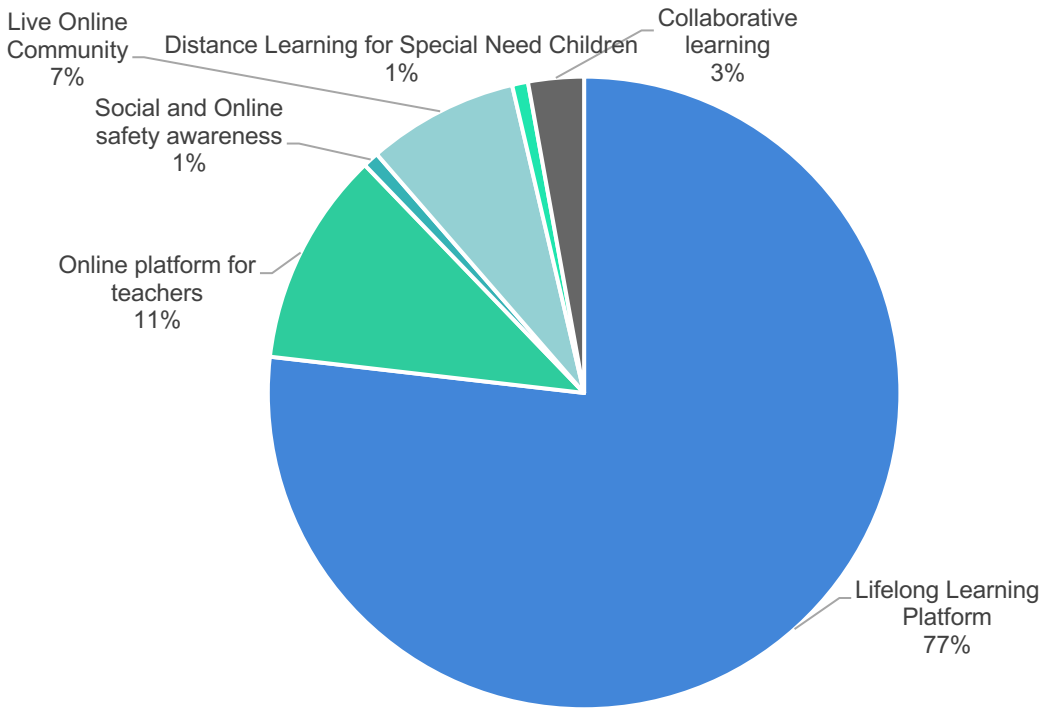

FIGURE 6 CLUSTERS USING DIGITAL EDUCATION PLATFORMS

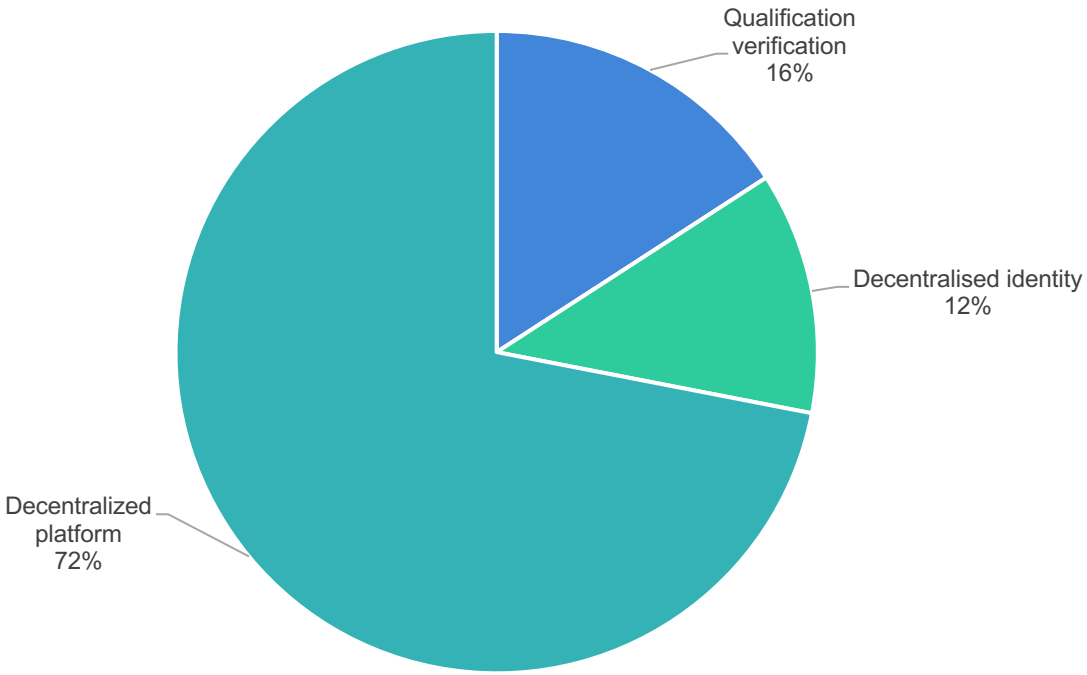

FIGURE 7 CLUSTERS USING BLOCKCHAIN

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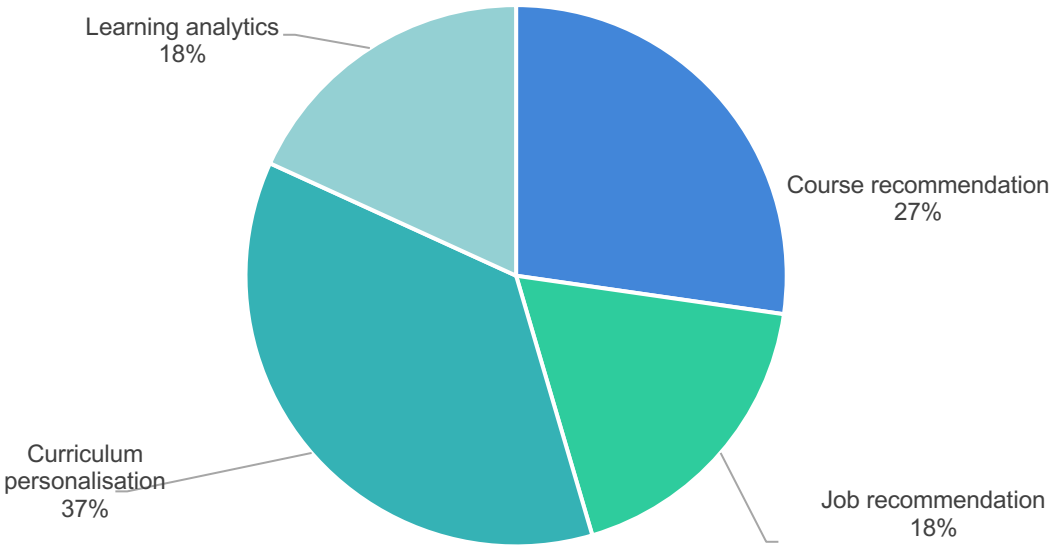

FIGURE 8 CLUSTERS USING MACHINE LEARNING

5.2 LEARNING ACTIVITIES

There are five learning activities identified earlier in the report. We observed those activities against the clusters of initiatives with a view to understand what kind of learning activities are amongst the most popular for technology use. Figure 9 shows content delivery is the most popular learning activity with diverse technological use cases, involving more than ten clusters, while credentials and recommendations technologies group around a smaller number of use cases, with only three clusters. Figure 10 shows they account for 39% and 11% of the total clusters.

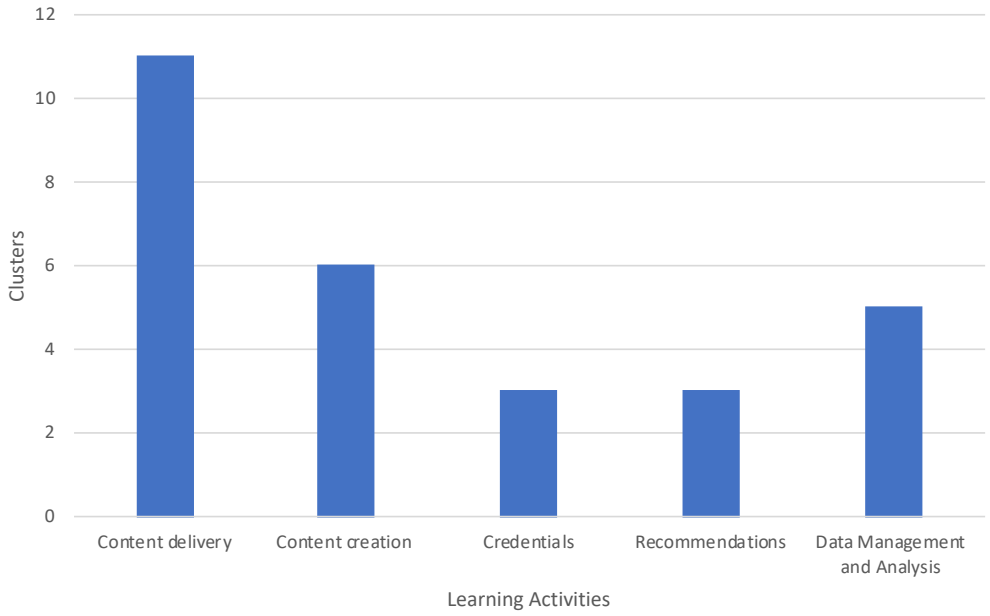

FIGURE 9 NUMBER OF CLUSTER AGAINST LEARNING ACTIVITIES

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There is, however, an interesting point to observe. All clusters covering credentials are based on blockchain technology, while recommendations involved only machine learning. Content creation is the second most popular learning activity with 21% clusters involved in it, while data management and analytics accounts for 18% clusters. It is noted that some clusters apply to more than one learning activity.

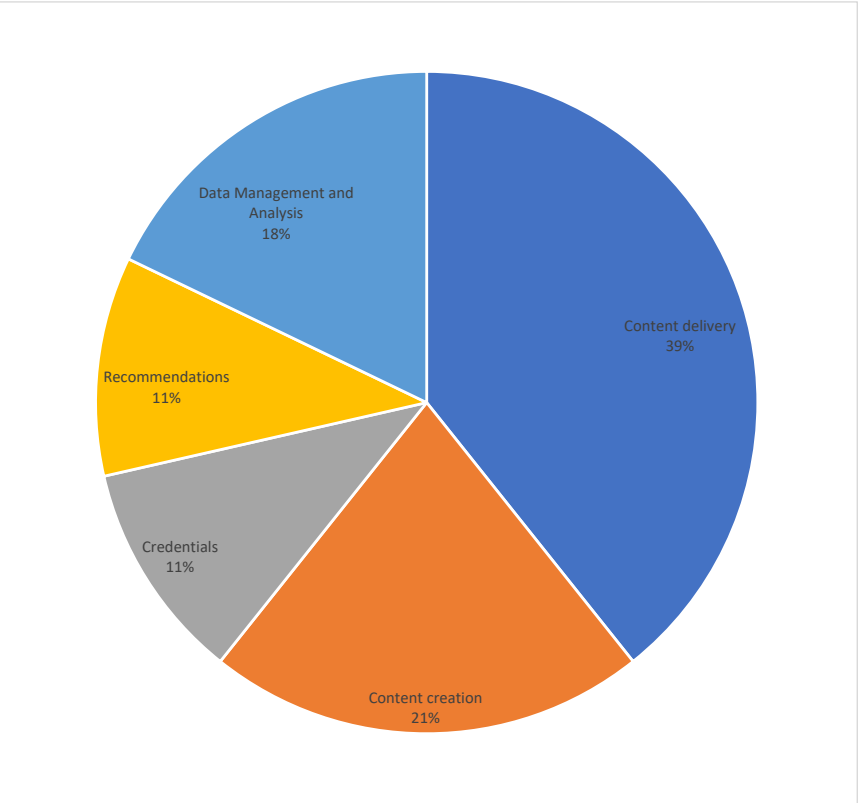

FIGURE 10 PERCENTAGE OF CLUSTERS AGAINST LEARNING ACTIVITIES

5.3 STAKEHOLDERS

Figure 11 shows amongst the stakeholders, both face-to-face teachers and learners have eight clusters, but online or blended teachers and learners have 14 and 16 clusters between them which is 35% and 31% of the clusters as shown in Figure 12. Content creators feature in 7 clusters, while employers and institutions are less targeted.

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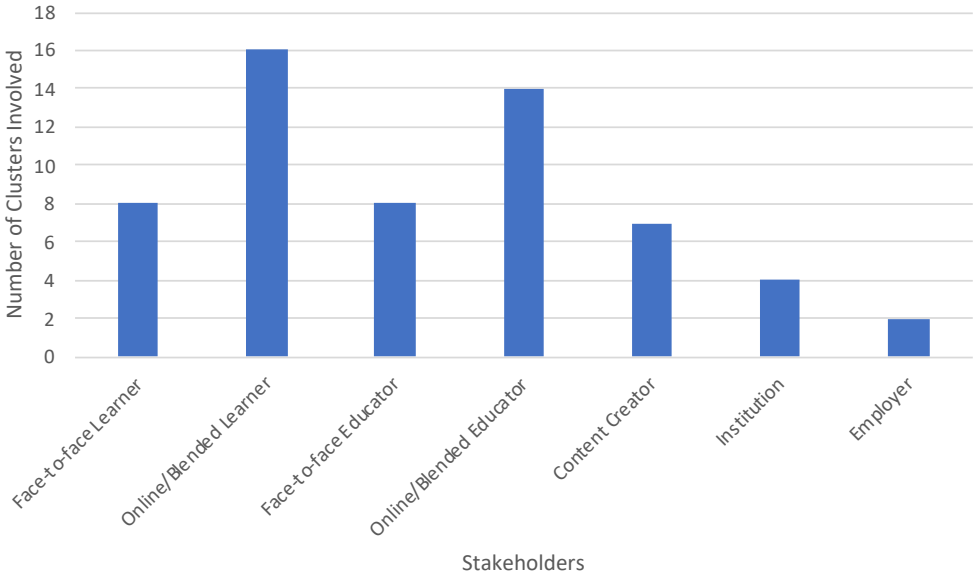

FIGURE 11 NUMBER OF CLUSTERS AGAINST STAKEHOLDERS

The data shows the diversity of stakeholders across the initiatives but also emphasises that learner/teacher-based use cases are most common amongst the DEL space. It is noted that some clusters support more than one type of stakeholder.

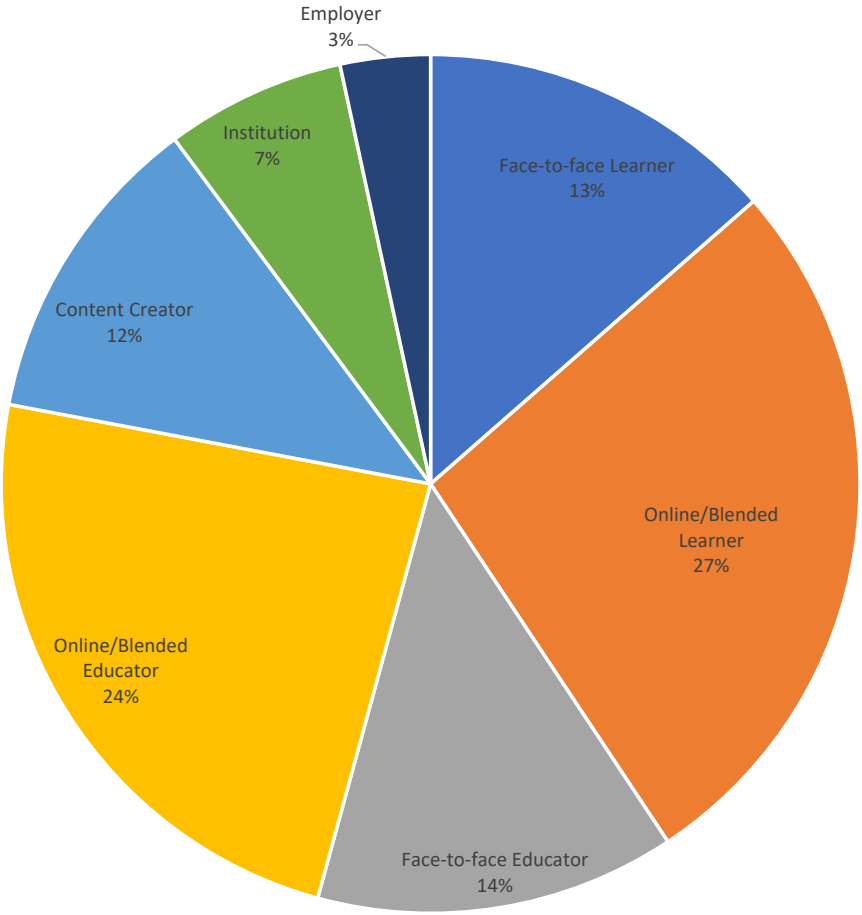

FIGURE 12 PERCENTAGE OF CLUSTERS AGAINST STAKEHOLDERS

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5.4 TYPES OF ORGANISATION

The last analysis we conducted on the types of organisations. Figure 13 shows that, amongst the 441 initiatives collected and observed, initiatives of the Platform and Research types are the most prominent. More than 130 initiatives for each of those types are found in the aggregator, accounting for 41% and 30% of the total observations, respectively. There are just below 40 initiatives for all other types except SMEs, that accounts for only 3% of the observation.

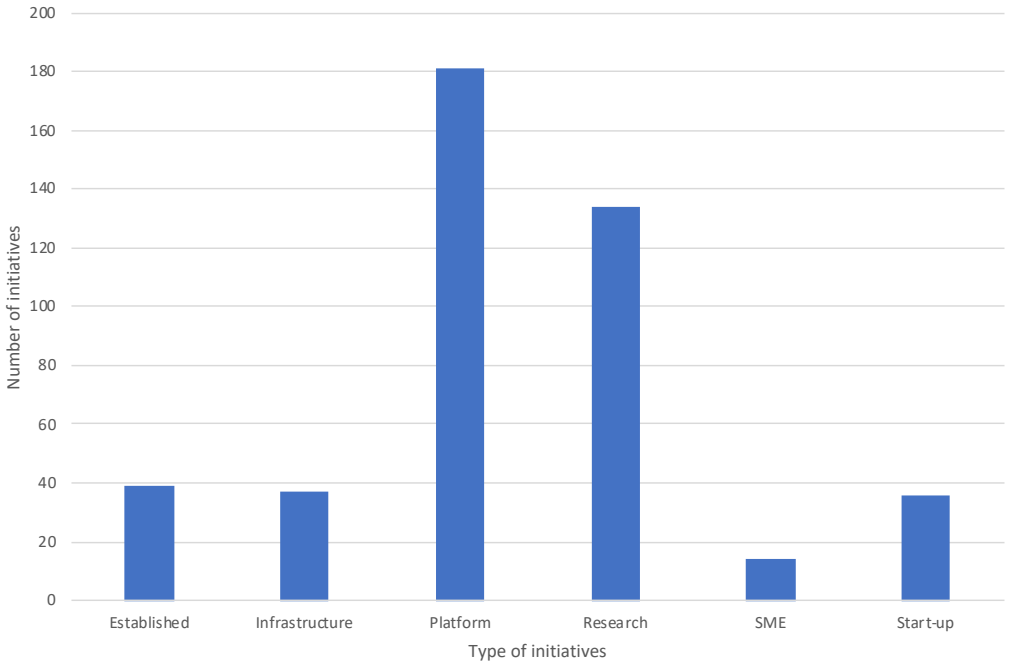

FIGURE 13 NUMBER OF INITIATIVES AGAINST TYPES

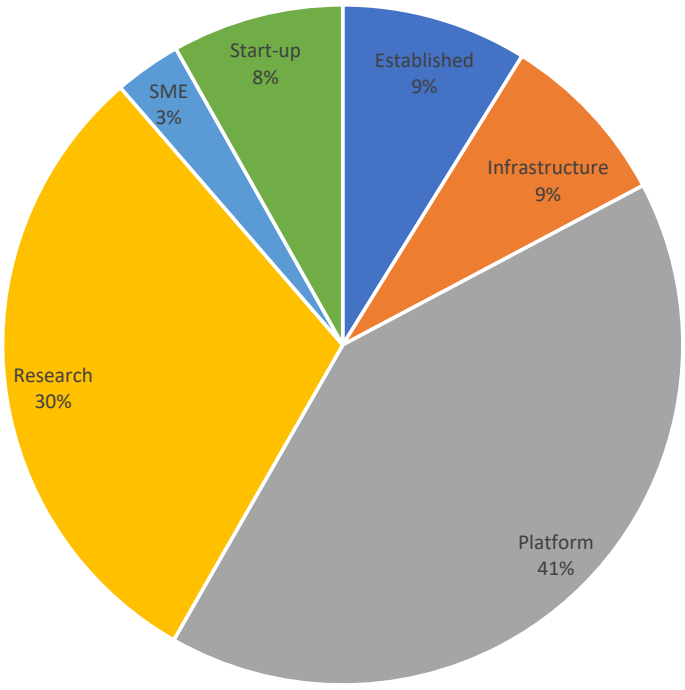

FIGURE 14 PERCENTAGE OF INITIATIVES AGAINST TYPES

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To wrap up the impact analysis, we created a chart taking the number of initiatives, their types, and the technology providing them, together. Figure 15 shows that amongst 441 initiatives, Platform and Research types offer the largest number of digital education providers. Platform type also provides the most initiatives involving AI and Blockchain technology while IoT providers are mostly research organisations. Start-ups are the third amongst the digital education providers. In addition to IoT, most initiatives that use technologies such as AR, Big Data, ML and VR are also provided by research organisations.

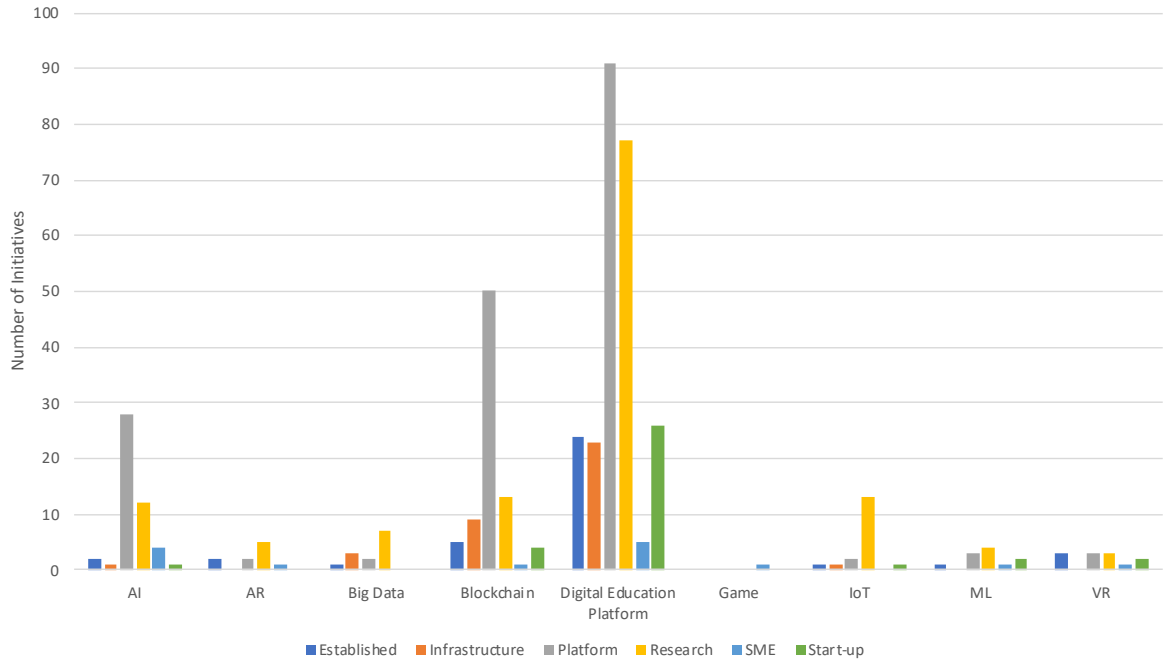

FIGURE 15 INITIATIVES, TYPES AND TECHNOLOGY

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6 CONCLUSION

We have used the DEL4ALL Technology vs. Education Matrix to analyse the current state of activity in the educational technology sphere with regard to scale, diversity, and maturity of initiatives across clusters of related topics. The results provide a number of visualisations making it easy to identify the current state with regard to each metric at a glance. Of course, this report presents only a summary at the aggregated level; the DEL4ALL online catalogue will, going forward, provide the means of using the various factors considered here in order to drill down the DEL4ALL portfolio of projects to individual initiatives or clusters. The current analysis is presented as a snapshot to be used as a lens into this data.

It is perhaps not a surprise to see that clearly the most active and diverse form of technology use in the current landscape is centred around digital education platforms, and AI and ML initiatives. Various forms of platform for supporting education have been in use for some time and are likely to involve concepts familiar to many involved in education. AI and ML, while only more recently, nonetheless have a relatively high awareness in public consciousness, and also, typically, do not necessarily require significant day-to-day changes in educational tasks to have an impact. By contrast, AR and VR, whose claimed educational benefits come from activities and exercises involving individual learners using specific hardware, are perhaps also unsurprisingly less active areas – development and adoption needing not only distribution/wide access to (in some cases, very expensive) hardware, but also to have been incorporated at the stage of educational planning and learning design. One might expect that blockchain technology, with relatively high levels of general public consciousness, may have been more strongly represented, but (in the authors' capacity as blockchain researchers), we note that this consciousness is often also accompanied with scepticism, and that there has been a noticeable "hype bubble" affecting perception of blockchain projects.

As a final conclusion to be noted from this analysis, the significance of digital education platforms and of technologies such as AI which may not require day-to-day changes confirms the anecdotal observation which multiple DEL4ALL project partners and participants have made during the COVID-19 disruption to education, which is that the use of technology in much of day-to-day education is concerned with basic technologies, rather than "advanced". A lesson we might learn from the pandemic, borne out by results such as these, is that more attention might have to be paid to examining the nature and scale of any such "gap" between current educational practice and research activity, and what (e.g., investment in intermediate stages of development) might address it.

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[1] *D1.2 DEL4ALL Technology vs. Education Matrix v2,* N. Chowdhury, A. Third, A. Grech, and S. Kolvenbach, https://www.del4all.eu/deliverables/, Jan 2021.

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