GAMIFICATION, EXTENDED REALITY, AND ARTIFICIAL INTELLIGENCE IN EDUCATION

A Review of Practices and Considerations for the NZ Food and Fibre Sector

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Learner-Focused, Industry-Led, Government-Enabled

PREPARED FOR:	New Zealand Food and Fibre Centre of Vocational Excellence
PREPARED BY:	David Penney, Consultant, Skills Group Taryn Eparaima, Consultant, Skills Group
CONTRIBUTORS:	Josh Williams, Lead Consultant, Skills Group Wyn Hughes, Senior Consultant, Skills Group
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ABBREVIATIONS

ABBREVIATION	DEFINITION
AI	Artificial Intelligence
ANI	Artificial Narrow Intelligence
AGI	Artificial General Intelligence
ASI	Artificial Super Intelligence
AR	Augmented Reality
FFCoVE	NZ Food and Fibre Centre of Vocational Excellence
GAM	Gamification
SG	Skills Group
STEM	Science, Technology, Engineering, and Mathematics
VET	Vocational Education and Training
VR	Virtual Reality
XR	Extended Reality

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INTRODUCTION

Background

The Food and Fibre industry is interested in exploring new and innovative ways to upskill, train and attract people in the primary sector. The rapid development of new technologies will undoubtably change the pattern of human work and how we train and educate people.

To ensure New Zealand remains innovative and competitive with the rest of the world, the New Zealand Food and Fibre Centre of Vocational Excellence (FFCoVE) wants to understand how emerging technology can be used in vocational education. Of particular interest is how these technologies can be used to train and support people to be 'work ready' as well as to help employers upskill existing staff.

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NZ Food and Fibre COVE
The New Zealand Food and Fibre COVE is a national body established by a consortium of 54 sector stakeholders to drive quality in the NZ vocational education system for the Food and Fibre sector.

Gamification (GAM), Extended reality (XR), and Artificial intelligence (AI) have been identified as three technologies of interest to the Food and Fibre sector due to their emerging, or apparent, relevance to educational environments. Food and Fibre sector stakeholders hypothesise that these technologies, when used as training and education tools, could lead to improved education system and industry productivity; better educational engagement and motivation; better health and safety outcomes; greater employee competency; and contribute to increased attraction and retention for the sector, compared to Vocational Education and Training (VET) which doesn't employ these technologies.

This paper explores the effectiveness and practicality of XR, AI, and GAM technologies within education environments, specifically vocational education environments. The purpose of this being to identify the relevance of these technologies and discuss what should be considered if any were to be implemented in the New Zealand Food and Fibre sector.

To do this, this paper reviews relevant information about these technologies and presents examples of where this technology is currently being used for educational purposes both in Aotearoa New Zealand and around the world. It will also consider the future of this technology in education and training and any implications for the Food and Fibre sector.

Consideration is given to how this technology might evolve in the immediate future (1-2 years), the next 2-5 years, and how the sector will need to adapt and be ready to embrace changes occurring at speed.

This paper focuses on the Food and Fibre sector, though its discussion is relevant to other sectors in New Zealand and examples outside of Food and Fibre have been used to demonstrate the educational applicability of these technologies regardless of industry.

Furthermore, the FFCoVE is interested in exploring pilot programmes to test the applicability and functionality of these technologies within an authentic education environment. The findings of this research will help inform the design and development of these pilot programmes.

Key Concepts

The following outlines the key concepts of Gamification, Extended Reality, and Artificial Intelligence, and offers context, and a working definition for each technology.

Gamification

Gamification is perhaps the most well-developed concept of the three areas this study is focused on, in terms of its adoption in vocational education, but it still has its nuances.

Gamification (GAM) refers to the application of elements traditionally found in games, both physical and digital, to non-gaming contexts (Deterding, DIxon, Khaled, & Nackle, 2011); these elements could be applied to systems, processes, learning activities, or other areas. This is an intentionally broad definition. Some prefer to narrow this definition depending on their contexts (See Krath, Schürmann, & Korflesch, 2021 for examples), but keeping this definition broad enables a wider discussion. Therefore, this report keeps it broad.

This might also be seen as more of a technique than a technology. Gamification is frequently enabled by, or reliant on, a piece of technology, but it doesn't necessarily require any 'technology'. For example, game elements that are incorporated into a physical environment might not even require any physical resources. This might stretch the concept beyond the way in which it is commonly used, but it is illustrative. For simplicity though, this report will refer to Gamification as a technology.

Further, differentiation is needed between **Gamification** and **game-based learning**. These two related concepts are commonly confused. Gamification is the act of introducing game-like elements to non-game environments; game-based learning is the use of an existing 'game', one intended for entertainment or other purposes, for learning (Bolstad & McDowall, 2019).

An example of game-based learning might be having students in a classroom environment play board games to learn about social interactions. A teacher might have students play these games and then reflect on the social elements embedded within them. Another example, one which uses technology, might be the use of video games to teach storyline analysis, or to develop cognitive skills. Educators might effectively select video games with interesting stories or themes for analysis, or they might offer others that have strong cognitive components to strengthen cognitive skills such as spatial reasoning or memory. It must be noted that both gamification and game-based learning should have strong educational justifications prior to implementation.

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A note on game-based learning terminology

Some researchers and expert practitioners are cautious about the term "game-based learning". [Some] (Shapiro, Tekinbaş, Schwartz, & Darvasi, 2014) suggest it "seems to be a misnomer, as the learning is not based on games, but enhanced by them". They describe games as "elastic tools" that can be "repurposed and modified to support curricular goals, as opposed to driving them". Some people prefer to use other terms such as game-infused, game-inspired, or "gameful" to describe the rich variety of practices in which games can be woven in, around, and through learning.

- Rachel Bolstad and Sue McDowall (2019)

Extended Reality

This study began with the remit to explore 'Virtual Reality' and how this technology could support and enhance vocational learning. This concept is relatively well understood, and the technology is already being implemented in various educational contexts. Upon inception, however, it was identified that this term by itself would not sufficiently enable a discussion of what was intended in this study's design: to explore digitally simulated elements and environments in an educational context.

In 'reality', virtual reality technologies represent only one part of a continuum of digital simulation technologies that are being applied to educational contexts. This continuum - termed the reality-virtuality continuum (Milgram, Takemura, Utsumi, & Kishino, 1995) - describes digital simulation concepts and technologies based on their presentation of physical (real) and digital elements and environments; a model of this is shown in Figure 1.

EXTENDED REALITY

Extended reality is the umbrella term for all digital simulations, whether these are presented in the physical (real) environment or within a digital environment.

This continuum presents the overarching concept of 'Extended Reality', or XR, as well as three semi-distinct concepts beneath this that will be referred to in this report: **Augmented Reality** (AR), **Mixed Reality** (MR), and **Virtual Reality** (VR).

Extended reality is the umbrella term for all digital simulations, whether these are presented in the physical (real) environment or within a digital environment.

At the most 'physical' end of the XR continuum is Augmented Reality, or AR. **Augmented reality** refers to a setting where the physical environment is overlaid, or 'augmented', with digital elements or simulations.

At the most 'digital' end of the XR continuum is **Virtual Reality**, or VR. **Virtual Reality** refers to a setting that is fully digitally simulated. 'Fully' is used loosely in this context as technology is not yet at a stage where an individual can immerse themselves 'fully' in a digital environment. Such an environment would conceptually require the believable simulation of all senses which humans have to engage with the physical environment. Nonetheless, VR technology is at a stage where visual and auditory stimuli can be presented convincingly, which is sufficient for a range of purposes. In fact, some contend that new language is needed to distinguish between VR experiences due to the wide range of experiences available through the technology that can be more-or-less complex and sensorily involved (Kardong-Edgren, Farra, Alinier, & Young, 2019).

Around the center of the continuum is Mixed Reality, or MR. **Mixed reality** refers to a setting that blends physical and digital elements in a way where both elements can be interacted with. Interaction is the key to this concept and is perhaps the reason why MR is the most difficult of these concepts to understand. While AR environments put digital elements into the physical environment, their digital elements cannot be directly interacted with. Contrastingly, VR environments intend to fully immerse an individual in a digital environment where the physical environment is excluded. It should be noted that different conceptualizations of MR also exist that give it more or less conceptual territory – language often lags behind technological change – but this study uses the definition above.

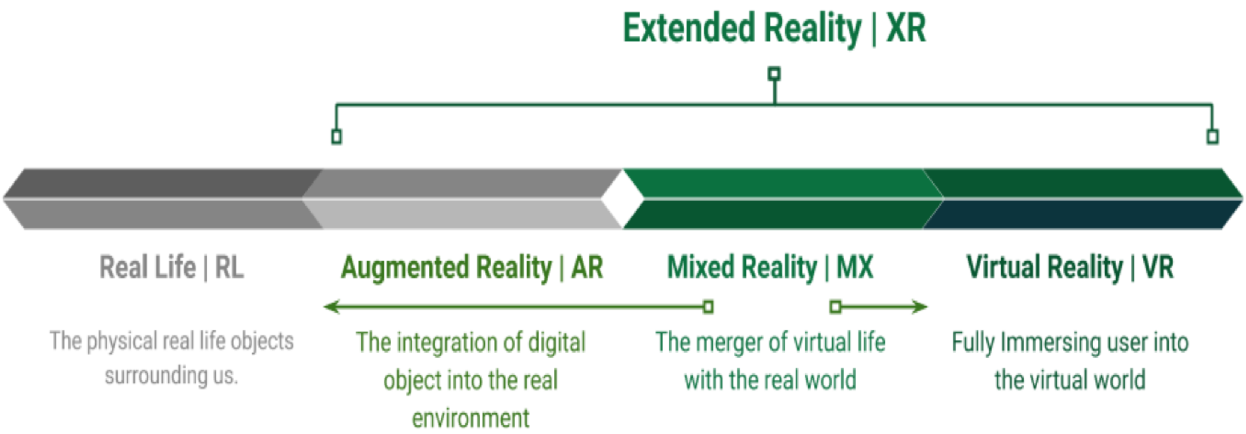

Figure 1: Reality-Virtuality Continuum, demonstrating relationships between XR, AR, MR, and VR. Source: (Cavus, Al-Dosakee, Abdi, & Sadiq, 2021)

Artificial Intelligence

Artificial intelligence, or AI, is a concept of increasingly robust discussion, spurred on by recent breakthroughs in artificial intelligence software that have been thrust into the mainstream – notably following the public release of OpenAI's 'Chat GPT' (Generative Pre-trained Transformer) in November 2022 (OpenAI, 2022). These breakthroughs have provided relatively open access to a suite of AI tools, particularly content generation tools, that are now being implemented in industry and for personal use. The world is in a stage of technological adaptation and incorporation, the future of which is unclear. What is clear, however, is that this technology and its certainly inbound iterations will have transformative impacts on the ways that we work, learn, and interact with the world around us.

Interestingly, and perhaps shockingly, this wave of technological development represents only a small fraction of what AI could be and do in the future. AI's known potential in terms of leading and augmenting education and training processes is enormous, though where the technology progresses to from here is far less certain. These are the early days of relatively widespread adoption and understanding and as such we have only a glimpse of the earliest (and most buggy) examples of these technologies. For the purposes of this research, we present an overview of how current and near future AI technologies could benefit educational contexts. To facilitate this, only a cursory level of understanding of AI is needed, enough to separate the facts of what AI is and what it is not.

ARTIFICIAL INTELLIGENCE

Artificial intelligence is, in its simplest form, any software which simulates human intelligence: the ability to acquire new information, to manipulate that information, and make reasoned judgements using that information.

Artificial intelligence is, in its simplest form[1], any software which simulates human intelligence (Copeland, 2023): the ability to acquire new information, to manipulate that information, and make reasoned judgements using that information.

Emerging from this definition are the three umbrella categories of AI often used to separate the AI fact from AI science fiction: Artificial Narrow Intelligence, Artificial General Intelligence, and Artificial Super Intelligence. These categories are based on the potential capabilities of an AI.

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[1] See Pei Wang's article, 'On Defining Artificial Intelligence, 2019' for a discussion about the difficulties in defining Artificial Intelligence.

Table 1: Categorisation of AI technology using current and future capabilities.

Artificial Narrow Intelligence	**Artificial Narrow Intelligence** (ANI), sometimes referred to as 'weak AI', refers to artificial intelligence tools that have been trained to perform a specific task or set of tasks, but which cannot perform in areas outside of what they were designed to do. This category completely covers AI tools currently available. Even the most sophisticated and seemingly 'intelligent' AI tools currently available are limited to certain tasks and are therefore ANI. Open AI's 'ChatGPT' is an example of ANI.
Artificial General Intelligence	**Artificial General Intelligence** (AGI), otherwise known as 'strong AI', is a conceptual category of AI that could perform a similar range of cognitive functions as humans. These AI would form connections and make generalisations across domains – they would learn, perceive, and understand like a human can. These AI do not currently exist, though work is being done with the aspiration of developing AGI. It is unclear how far away these types of AI might be; though, much of the technological groundwork has been laid with the development of supercomputers and increasingly sophisticated ANI.
Artificial Super Intelligence	**Artificial Super Intelligence** (ASI) refers to a category of AI that could perform a range of cognitive functions to a level exceeding human capability. This is the category most associated with science fiction, fueling many arguments for the control and regulation of AI technology. Along with AGI, the impacts of ASI can only be speculated on at this time and are well beyond the scope of anything available today. It is likely that ASI would represent an even greater transformation of the world than AGI.

With current AI technologies limited to the capability-category of Artificial Narrow Intelligence, when AI is referenced through this report it is considered to refer to ANI unless otherwise stated.

Another categorisation of AI comes from the technical functions it can perform. Understandably, this categorisation is rooted in our currently available technology and limited vision into the future. It does, however, give additional insight into the current technological landscape of AI. This model has four ordinal categories: Reactive Machines, Limited Memory, Theory of Mind, and Self-Aware.

Table 2: Categorisation of AI technology using current and future technical functions.

Reactive Machines	**Reactive Machines** are AI that can react to stimuli and respond to immediate tasks but are unable to store memory or learn from their experiences. These were the first AI to be developed. Examples of these AI include chess playing systems and content recommendations for streaming services. All take inputs and provide outputs based upon their training in defined conditions.
Limited Memory AI	**Limited Memory AI** are those which are still narrow in their focus, like reactive machines, though have the ability to store information to refer to or make inferences from. Some might store this for future learning, but most only use this memory temporarily. This functional categorisation is where most sophisticated AI emerging today are situated within. An example within this category is the software supporting self-driving cars. This software takes inputs continuously while driving, storing it in memory, and making decisions about which actions to take as a result. In this way, AI with this specific functionality can be applied in more generic circumstances than reactive machines.
Theory of Mind AI	**Theory of Mind AI** is a conceptual category which would include the capabilities of both Reactive Machines and Limited Memory AI, though with the added function of being able to interpret and respond to emotional and instinctive cues. This functionality would enable AI to understand and predict behaviour.
Self-Aware AI	**Self-Aware AI** would emerge after Theory of Mind AI. These are categorised as those with not only a sense of others and their emotional states but be aware of themselves as an entity.

Another important distinction that should be made is that of a certain subset of AI that have been emerging recently: '**Generative AI**'. These types of AI are categorised as 'Narrow AI' – they have been trained to perform a single function or set of functions but not to work beyond these – and refer to AI that use algorithms to generate original content based on prompts given by a user. Generative AI tools have now emerged that can generate text-based content, images, videos, audio, and more with varying degrees of validity, accuracy, and, perhaps what some might consider, creativity. Some might also consider these Generative AI as bordering on the edge of being classified as 'Artificial General Intelligence' due to their functions being so broad, particularly in the text-based content generation space, but most would probably agree that these tools don't come that close to the upgraded classification.

We can compare these Generative AI with the wider range of AI tools available today – all other AI tools that exist – those that we will term **'General AI'**. Where relevant, this study will make clear where it is referring to General AI or Generative AI, as their benefits and potential challenges are distinct in some areas.

These have been relatively simple explanations, and these concepts will likely be refined in future as emerging technological developments reshape our understanding. Most importantly, it is necessary to understand that AI in practice is different to what has been presented in many types of media. Current AI has certain limitations, though the field is developing quickly and, even now, AI models have enormous potential to be applied in many settings, including education.

CHALLENGES IN DEFINING AI

Different definitions of AI have emerged in different domains based upon what they are needed for in each (Wang, 2008). For example, computer scientists have created technical definitions, whereas policy and legal practitioners have created capability-bound definitions (P. M. Krafft, 2020).

Understanding these points, however, is sufficient to discuss the current developments in AI and their potential for education contexts.

Gamification

Using game elements, physical or digital, in non-gaming contexts.

Extended Reality

Digitally simulated elements presented in either the physical (real) environment or digital environment.

Artificial Intelligence

Software that simulates human intelligence.

GAMIFICATION IN EDUCATION

Uses and Benefits of GAM in Education

How can GAM be applied within education?

Gamification (GAM) has applications across a range of contexts. In fact, the term originated from the development of game-like interfaces for automatic-teller and vending machines (Christians, 2018). It is not a native concept to education[2]. A somewhat recent review of gamification studies (Hamari, Koivisto, & Sarsa, 2014) identified studies exploring gamification concepts in the areas of:

- Education
- Commerce
- Health/Exercise
- Intra-organisational systems
- Sharing
- Sustainable consumption
- Work
- Innovation/Ideation
- Data gathering

Despite taking a wide view about what constitutes GAM (using a psychological model based on generating motivation to drive behavioural change), this review demonstrates the wide applicability of this type of technology – particularly as a tool for potential motivation and engagement. This review also identified education as the sector with the most GAM studies related to it. It appears that GAM has substantial face-value relevance to the education sector, or at least captures research attention in this space.

A recent narrative review of GAM case studies presents a list of game principles that could be relevant to education (Doney, 2019). Those which were assessed by the author to have the most

[2] For some examples of gamification outside of education, as well as some within education, see (Kim, 2015).

impact are shown in Table 3, along with their purported degree of relevance for gamified experiences[3].

Further to and supplementing these principles, games have three main categories of features that might be used to gamify experiences, though not all are unique to games (Kiryakova, Angelova, & Yordanova, 2014) (Bunchball, 2012) (Bevins & Howard, 2018):

- **Performance-related features**, such as real-time feedback, freedom to fail, transparency of progress, goal-orientation, challenges, or user participation.
- **Achievement-related features**, such as badges, points, progression/levelling up, rewards, or on-boarding/tutorials and mastery.
- **Social features**, such as competition, rankings, or the use of teams.

Table 3: Game principles and their relevance to gamified educational experiences.

GAME PRINCIPLE	RELEVANCE TO EDUCATION
Challenge, the level of difficulty and ability to stretch the learner.	**High** – having the correct level of challenge for the audience is crucial for successful game-based learning.
Competition against the game or other players, which can be a motivating factor and encourage learners to repeat tasks to improve.	**Low** – the use of competition against the computer, self or others can be a motivating factor, but some people can find it off-putting, and there are some arguments that extrinsic motivation (the desire to gain a high score) can have a detrimental effect on deeper learning.
Control, which relates to the ability of the learners to manipulate their environment.	**Low** – the ability of learners to manipulate or control their environment can be a useful learning tool; however, this may not be possible in all game types.
Feedback, a crucial element of the learning cycle, enabling users to learn from actions and errors.	**High** – feedback is required to allow players to learn from actions and errors.
Interaction with game characters or other players (and in some cases tutors or moderators).	**High/Medium** – interaction can be with the game (controls within the game, characters), other players or facilitators/tutors. Communication with others can encourage peer learning and deeper engagement.

[3] Note that this review has an e-learning lens, but its findings surrounding game principles and their relevance can be applied to all manner of gamified experiences. This review also contains a set of aggregated considerations for the development of gamified educational experiences from the case studies it analysed.

Representation, which can relate to the game's environment, the realism of scenarios and the use of visuals and media.	**High/medium** – visuals and multimedia can help learners to engage with the game. In scenarios and simulations, it appears to be more important that the situation and results of actions appear to be realistic than the complexity of the visual environment.
Rules and/or goals, which allow learners to understand how to play the game and what they need to achieve.	**High** – these are required for learners to be aware of what is required and have a clear understanding of the learning outcomes.
Reflection, providing learners with the chance to reflect on learning (something often not present in games, where the emphasis may be more on speed or scores).	**Medium** – this would depend on the subject covered and the complexity of learning; however, providing opportunities for learners to reflect (by providing reasons for choices or discussing with others) may encourage deeper learning.

GAM Benefits to Education

GAM is primarily used within the education sector to **enhance learning design and delivery**. This area draws the attention of most educational GAM studies. In this area, two types of GAM are conceptually present: structural gamification and content gamification (Garone & Nesteriuk, 2019). Structural GAM refers to the application of game elements to instructional content without changing the content; often, these GAM efforts relate to achievement-related features of games. Content GAM refers to game elements being applied to instructional content itself wherein the delivery mechanisms or strategies are adapted to include game principles or elements.

When used for learning design and delivery, gamification intends to deliver a mix of three key stepwise benefits[4]:

1. Increased **motivation** of learners
2. Increased **engagement** of learners
3. Increased **performance** of learners

Of these intended benefits for learning design and delivery, motivation and engagement are often the core focus of GAM. This is because some hypothesise that GAM is not directly associated with knowledge and skills; GAM influences learners' behaviour, engagement, and motivation, which can subsequently lead to improved performance (Huang & Soman, 2013). Some proponents of game-based learning might disagree that performance cannot be directly influenced through GAM; though, most appear to use GAM to target learner motivation and engagement as pre-cursors to performance.

[4] Other areas that are targeted by some GAM interventions include 'playfulness' and 'learner perceptions', the latter including satisfaction and enjoyment (Bevins & Howard, 2018).

A recent review of GAM in education reported that **GAM can have positive impacts on student motivation, engagement, and academic performance** (Manzano-León, et al., 2021)[5]. These effects were found to be possible at various levels of education, from school to university-level. It is important to note, however, that vocational education was not within the scope of this study and most related studies focus on the higher-education sector. These findings are reinforced by a 2020 meta-analysis by Sailer and Homner which found that gamified learning experiences could deliver small increases in the achievement of cognitive, motivational, and behavioural learning outcomes, indicating that GAM might be an effective tool (Sailer & Homner, 2020). Though it should be reinforced that these impacts were small.

These types of impacts are, however, not achieved by all gamified experiences and some question GAM's effectiveness.

The following section gives an overview of some key considerations and challenges for engaging in GAM, as well as factors that influence the effectiveness of gamified products and solutions.

Challenges with GAM in Education

A range of studies have identified gamified experiences that did not had any positive effects on these areas and several have also reported negative effects from gamification too (Dicheva & Dichev, 2015) (Roy & Zaman, 2017). Gamified learning experiences can differ in the quality of their design or implementation.

This is likely due, in part, to the diverse range of GAM learning experiences and game-elements being used in them, as well as the relatively limited understanding of the mechanisms through which GAM can cause these benefits[6]. Beyond identifying some positive impacts of GAM, the Sailer and Homner study identified that the factors contributing to successful gamification in education are largely not understood, particularly for cognitive learning outcomes (Sailer & Homner, 2020). Despite this, GAM's penetration of education is increasing and has outpaced researchers' understanding of the practice (Dicheva & Dichev, 2015). Many researchers are more concerned with *whether* GAM can produce these benefits than *how* it does so (Roy & Zaman, 2017). This has left a gap in understanding how to effectively implement GAM in education, and many poorly designed GAM activities have been implemented with inadequate design processes or guidance to support them (Mora, Riera, Gonzalez, & Arnedo-Moreno, 2015).

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[5] This study also discusses some of the possible mechanisms that might result in GAM's impacts in these areas. For another discussion on educational GAM mechanisms from a user perspective, see (Bolstad & McDowall, 2019).

[6] Other explanations for the mixed results of GAM studies include learner outcomes being temporary due to the technology being 'novel' and poor-quality pedagogical design or GAM implementation designs (Roy & Zaman, 2017).

For example, achievement-related game features such as points, leader boards, and badges are the most commonly studied in general GAM research (Hamari, Koivisto, & Sarsa, 2014). This does not necessarily mean that these features are the most important or impactful to GAM experiences, though. It is possible that they are overrepresented as the features are easy to implement or because they are more useful to contexts outside of education. It has also been found that when these achievement-related factors are implemented in isolation they can have negative effects on learner outcomes such as motivation or performance (Roy & Zaman, 2017).

Some put forward that GAM can achieve its purported benefits by supporting curiosity and experimentation; cultivating a positive attitude to failure; delivering individualised learning appropriate to the level and pace of the learner; and facilitating focus and flow (Australian Government Department of Education, 2022). Other explanations describe games and game-principles as naturally motivating and engaging but do not provide evidence for this. It is perhaps that this is intuitive and that evidence for this is not needed; though, given the evidence that not all are motivated or engaged by games and game principles equally (Kapp, 2013), it is sensible to conclude that this is not the case.

Further evidence for GAM mechanisms is needed, but one promising study attempts to provide an overview of how GAM works using self-determination theory (Ryan & Deci, 2000) – it puts forward that GAM activities should be viewed and designed holistically with consideration of how user characteristics, contextual demands, and system properties interact to affect the effectiveness of the GAM activity (Roy & Zaman, 2017). These factors have been validated in other studies too (Hamari, Koivisto, & Sarsa, 2014). When designing GAM experiences for learning, these three factors should be considered in equal measure.

GAM BEYOND LEARNING DESIGN & DELIVERY

While not the primary use case of GAM in education, historically speaking, there is potential for GAM to be applied beyond learning design and delivery.

Some might consider using GAM tools or techniques to support the motivation and engagement of stakeholders in their organisations or networks. The specific strategies for this fall beyond the scope of this review, though.

So, whilst this report concludes that GAM has the potential to benefit educational environments and programmes, it does so with caution and context. The field needs a greater understanding of how GAM elements can create conditions for learning benefits and what factors cause GAM to fail in an educational context.

The Wrong Reasons to use GAM

Karl Kapp, a leading thinker in the GAM space, gives several 'wrong' reasons to engage in GAM that are a good introduction to this topic. These include (Kapp, 2013):

- Engaging in GAM because it appears fun or popular. While gamified experiences can be engaging, this does not necessarily mean that they will result in learning.
- Deciding to apply GAM principles because others are doing it. While gamified experiences can work in some circumstances, they may not work in other, seemingly similar, circumstances.
- Developing GAM as a means to 'disguise' learning. Research supports the view that learners retain learning for longer when they know what they are learning.
- Developing GAM under the assumption that 'everyone enjoys games and GAM principles'. Learner factors and perspectives on GAM have been demonstrated to have a large mediation effect on GAM success.
- Developing GAM programmes or activities with the view that they will be simple to design.

Key Considerations for GAM Design

The Australian Government Department of Education also provide a series of cautions for GAM in education. These are in the context of Science, Technology, Engineering, and Mathematics (STEM) education, but are applicable more widely (Australian Government Department of Education, 2022). These are that:

- Not all learning can be gamified.
- Gamification should be balanced with other teaching approaches.
- Gamification can be a distraction if not well-linked with learning objectives.
- Gamification may foster extrinsic rather than intrinsic motivation.

To extend upon these, there are two key factors which influence the success of a GAM programme or activity: the context of the GAM and the users of the GAM product (Hamari, Koivisto, & Sarsa, 2014). The context of GAM referring to the particular programme, activity, or other area that is being gamified, as well as how it is accessed; the users of the GAM product referring to the profiles, preferences, and attitudes of the group being targeted by the GAM product. This section briefly explains these keys areas and then supplements them with a set of considerations for GAM in education.

GAM Context: The importance of evidence-based design

GAM activities see mixed effectiveness between sectors – such as between education and marketing – and within these areas. There is sufficient evidence to say that GAM efforts in education can support positive outcomes for learners, programmes, and possibly learning systems, but only when effectively designed for the context they are situated within.

The area that is being gamified and the environment it will be accessed within can change how GAM should be designed and implemented. For example, different learning programmes might benefit from different game elements being embedded within them depending on their learning outcomes;

learning programmes and learning management systems might be gamified in very different ways and for different purposes; and a gamified learning programme that is intended to be accessed in a self-directed manner may be gamified in a different way to a similar programme that intends to be delivered in a classroom environment.

GAM in education should critically consider the nature of the programme, activity, or element that is being gamified, as well as the challenge that it intends to address and the outcomes it intends to achieve to do so (context).

To account for varying contexts, GAM initiatives should be justified by needs analyses and need to be effectively designed. However, within education, GAM initiatives have frequently been found to be implemented without adequate underpinning rationale or design frameworks (Mora, Riera, Gonzalez, & Arnedo-Moreno, 2015)[7]. Design frameworks and processes are crucial to implementing purposeful GAM initiatives as they outline the intended outcomes of GAM; the context of the programme or activity to be gamified; and connect these to the mechanisms, GAM or otherwise, which would facilitate them. Without evidence-informed design, gamified programmes or activities are at a high risk of being irrelevant, ineffective, or, worse, harmful.

GAM Users: The importance of flexibility

Learner, or user, qualities – demographic, attitudinal, or otherwise – can impact the success of GAM. People tend to interact with game-like systems in different ways and for different reasons; therefore, their experiences with them are likely to vary (Hamari, Koivisto, & Sarsa, 2014). For example, different groups will have had different experiences with games and gamified experiences before. They might also hold pre-conceived ideas about what GAM is, or its effectiveness, as a result. Just as learners' attitudes and preferences to traditional education methods can vary widely, so too can their attitudes and preferences toward, and within, gamified experiences. Some GAM elements that are enjoyed by some may be disliked by others; some GAM experiences that are motivating, enjoyable, and performance-enhancing for some, may not be for others.

This also has implications for neurodiverse and marginalised learner groups. As these groups have different abilities to access and engage with traditional learning methods, consideration must be given to how they might engage with GAM experiences. Gamified experiences might provide additional barriers for these groups. There has only been a limited amount of research on GAM for neurodiverse learners, though it should be noted that some success has been seen with gamified experiences that specifically target some neurodiverse learners. Examples of this include game-based learning for the development and practice of self-regulation, attention, and communication skills. (Motti, 2019). It has been recommended that practitioners designing gamified experiences, or other emerging technologies, for neurodiverse learners do so with the inclusion of stakeholders who understand these learners' needs (Motti, 2019).

When creating gamified experiences, it is important to consider who the target audience of the experience will be and design with them in mind. It is also often advised that

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[7] For an interesting presentation of GAM design frameworks in education see the 2019 review by Priscilla Garone and Sergio Nesteriuk (Garone & Nesteriuk, 2019).

flexibility is built into gamified experiences to account for user differences (Khaldi, Bouzidi, & Nader, 2023)**.**

GAM Recommendations

Rob van Roy and Beike Zaman propose a series of recommendations for practitioners developing GAM experiences in education based upon basic psychological needs of learners (Roy & Zaman, 2017). Not all these recommendations will be relevant to all GAM efforts – and they may be too conceptual for some – but they are interesting to consider. They are:

- To support a learner's need for autonomy:
    - **Avoid obligatory uses**. Avoid forcing the user to use (a part of) the gamified system so as not to give them the feeling of being controlled.
    - **Provide a moderate amount of meaningful options**. Find the sweet spot between supporting users' autonomy by providing them with at least one option that is meaningful and complies with their values, while avoiding placing them in a dilemma by offering too many options.

- To support a learner's competence:
    - **Set challenging, but manageable goals**. To support the user's feelings of competence, create tasks that pose a significant challenge while remaining perceived as feasible to fulfil.
    - **Provide positive, competence-related feedback**. Support feelings of competence by integrating feedback mechanisms that positively inform learners about their progress in gaining competences and avoid negative feedback.

- To support learner's need for relatedness:
    - **Facilitate social interaction**. Eliminate factors that hinder social interactions between users and facilitate them to interact and support their feelings of relatedness instead.

- To acknowledge the interplay between these needs:
    - **When supporting a particular psychological need, be wary to not thwart the other needs** (referring to the recommendations, as each targets a particular psychological need). When designing a specific element to support users in one of their basic psychological needs, be wary to not thwart one of the other needs.

- To integrate gamification with the activity:
    - **Align gamification with the goal of the activity in question**. Alight the motivational pull of gamification with the goal of the activity, as such tuning gamification to both facilitate motivation and goal achievement.

- To acknowledge contextual factors:
    - **Create a need-supporting context.** To support the user's basic psychological needs, the gamified system should be implemented in a setting that is perceived as open

and supporting as opposed to controlling.

- To acknowledge individual differences and characteristics:
    - **Make the system flexible.** To account for personal differences, the gamified system should be flexible and adaptable to comply with the users' personal needs and preferences.

Examples of GAM in Education

Table 4: Brief examples of Gamification in Education.

EXAMPLE	EXPLANATION
Duolingo	Duolingo is a language learning tool that can be used by students and teachers as a gamified way to learn new languages. It is app based and uses avatars, badges, in game rewards, and other game elements to engage learners in learning.
Kahoot	Kahoot is a game-based learning platform that has learning games, also known as 'kahoots', which are user-generated multiple-choice quizzes that can be accessed via a web browser or app.
Poll everywhere	Poll Everywhere is used to create polls ahead of time which can then be used during classes to collect and display real-time responses that students provide with a laptop or mobile device.
Answer garden	Answer Garden is a free web-based tool that can be used to instantly collect short (up to 40 characters) text-based feedback from students. Instructors post a question or topic and invite students to enter responses. If multiple students enter the same response, a world cloud is formed.
Pecha Kucha	Pecha Kucha is a presentation method that calls for telling a story using images rather than reading text from slides during a PowerPoint presentation. Pecha Kucha presentations use 20 slides and allow only 20 seconds of commentary per slide. That keeps a total presentation to just 6 minutes and 40 seconds.
Padlet	Padlet is an easy-to-use online tool that allows students to work and interact collaboratively online. Users can post content and comments in real-time. Most types of digital content can be added to a Padlet (e.g., text, images, linked videos, and voice recordings).

Summary

In summary, GAM has potential applications within the education sector, however, it should not be engaged in without being well thought through. With GAM efforts seeing mixed efficacy in the literature, it is important that any efforts to develop in this area are evidence-based and outcome focused.

The cautions provided emphasize the importance of judiciously applying GAM, recognizing that it may not be suitable for all types of learning, and that it should be harmoniously integrated with other teaching methods. It also underscores the necessity of aligning GAM with clear learning objectives to prevent distraction and promote intrinsic motivation.

Moreover, the two key factors that influence the success of GAM, namely the context and the users, highlight the need for evidence-based design. Effective GAM initiatives should be tailored to the specific educational context and the goals they intend to achieve. Without a well-defined rationale and design framework, gamified programs risk being ineffective or even counterproductive.

Understanding the diversity of users, their preferences, and the potential impact on learner groups such as neurodiverse individuals is paramount. Flexibility and thoughtful consideration of the target audience are essential in designing successful gamified experiences. Furthermore, aligning GAM with basic psychological needs, such as autonomy, competence, and relatedness, is a powerful approach to enhance learner engagement and motivation.

EXTENDED REALITY IN EDUCATION

Uses and Benefits of XR in Education

Extended Reality (XR) – defined as including Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR) – has a long history in both art and technology (Xing, et al., 2021). Historically, artists and designers have imagined ways that humans could extend their 'real' reality with simulated realities or elements, but without the innovations to develop these. Technology is now, and for some time has been, evolving rapidly in the XR space; it can now, in many instances, fulfil the imagined functions of these thinkers from not too long ago. This relationship between art and technology has also been synergistic, with technology enabling designers and designers inspiring new technologies in the area (Xing, et al., 2021). Resultantly, the XR area is expanding, bringing with it new use cases and goals for these technologies.

This growth of, and developments within, the XR area justify the question: how could XR technologies be utilised in the education sector? To answer this question, not only should current technologies and initiatives be evaluated, but emerging and further-future technologies should be considered – in a manner similar to the imaginative thinkers of the recent past. This section discusses these points and the benefits these technologies could bring in this area.

The Potential Uses of XR

A Look to the XR Future

How might digitally simulated environments or elements be applied within education? This is the question being asked when outlining the potential applications of XR technologies: technologies that bring digital elements into the 'real' world or bring the user into a digital world.

The nuance to this question comes when considering what 'simulation' is. A true and 'full' simulation would be one that engages all five primary senses: sight, sound, smell, touch, and taste. Digitally simulating all these senses is currently unachievable using today's technology, but it might not be in future. There is almost certainly a future where technology will enable digital, or mixed digital and non-digital, simulations to do this.

In this future, however, the marginal impacts of each simulated sense on learning or education would need to be considered. These disaggregated impacts have been largely unexplored; many of the technologies necessary to create simulations for these senses do not yet exist. It is possible that different senses will result in different levels of 'immersion' in these simulations, possibly having varying impacts on learner engagement and learning delivery too. It is also likely that simulations to stimulate different senses will be of varied relevance to different learning concepts or environments. Simulating the smell of foods for culinary courses or hazardous substances for workplace safety training certainly *feels* more appropriate than simulating the smell of, say, a milking shed for an agricultural course. As with all quality learning activities, all aspects of the activity that are included should be relevant to, or enabling of, the learning that is intended.

While the future of XR technologies might be capable of offering sensorially 'complete' experiences, future learning designers will need to consider whether the inclusion of various sensory elements enhances their learning programme or not. This will need to be informed by research focused on the technologies that enable these as they emerge. Similarly, current learning designers need to consider how sensory simulations can add to their programmes.

Will sensorially 'complete' simulations ever be necessary?

"…as entertaining as [a fully immersive simulation is], do we really want, or even need, a fully immersive and interactive experience? From the perspective of pedagogical effectiveness and student engagement, perhaps not. AR may, in fact, be the technology that has greater potential as a pedagogical tool precisely because it allows the user to learn in a digital environment while always keeping a strong foothold in the physical world—a reminder that the [digital] world is not, ultimately, a real place."

- Tamara F. O'Callaghan (O'Callaghan, 2020)

Current XR Capabilities

Currently, XR technologies can simulate visual and aural elements effectively, but smell, touch, and taste are more complex to simulate and are beyond current technological limitations.

There are promising efforts to digitally simulate the sense of touch (haptics) in VR environments – such as haptic gloves which control the sensations your hands feel in these environments[8] – though

[8] For an understanding of haptic gloves, see Perret and Vander Poorten's 2018 analysis (Perret & Poorten, 2018). Though, this was several years ago and new products have emerged since publication.

the technologies to do so are not yet mainstream and require further development. There are also more substantial haptics technologies that are emerging, such as omni-directional treadmills which allow the user to feel the sensation of walking in VR whilst being harnessed to a stationary location. The sense of 'touch' is likely the next to be effectively simulated and mainstreamed. Many haptic technologies are, however, already being used in the education sector. They have particular value when applied alongside props in VR: a user can use their hands naturally in the virtual environment using haptic gloves to interact with a physical prop that is linked with a digital representation. This MR technique allows a VR user to interact with a physical object to simulate the feeling of touch, while this object is represented as something else within the virtual environment.

There are also limited efforts to develop digital simulations of smell and taste. One such example is the 'Digital Lollipop' research by Nimesha Ranasinghe and Ellen Yi Luen Do (Ranasinghe & Do, 2016). This research demonstrated that electrical signals sent to the tongue could be used to simulate basic flavour profiles including sour, salty, bitter, and sweet. These technologies are likely to be much further away than haptic technologies but will likely emerge eventually.

Current XR Uses

So, as effective visual and aural simulations are available across the AR, MR, and XR spectrum, and effective haptic simulations are emerging, how can the education sector use these technologies?[9] How can simulated visual, aural, and haptic elements support learning?

For visual simulations in **AR**, users require a digital 'window' to overlay digital elements onto the physical world. This could be a smartphone, smart glasses, or a Head Mounted Display (HMD) with passthrough functionality – external cameras that allow the user to selectively see the real world outside of the headset. Aural simulations in AR can come from anywhere, and haptic simulations are not widely used in AR.

Common AR techniques are:

1. **Information presentation** – Information can be overlaid on the physical environment through various means. The user might select certain information to receive, such as using smart glasses to simultaneously watch a tutorial and complete the task. The information might otherwise be prompted by scanning real world images. This could be in the form of information panels, various types of media, et cetera.
2. **Location detection and modelling** – AR devices can display 3D models in the physical world. Looking at a flat surface or a specified area, AR tools can recognise this and overlay models onto them.
3. **Object recognition and manipulation** – Bordering on MR, this technique allows three-dimensional (*3-D*) objects to be overlaid onto an AR tool, often a cube with QR (quick response) codes, which can then be manipulated by moving the object and can be engaged with through the AR interface.

[99] The literature review by Alnagrat et al. includes a more detailed discussion of different XR hardware and how they relate to education (Alnagrat, Ismail, Idrus, & Alfaqi, 2022).

By overlaying information in the physical world, learners can access 'just-in-time' relevant information to their context by scanning physical prompts. Further, using some hardware, information can be overlaid in a way that does not restrict the user from performing other tasks – such as with smart glasses. AR simulations might also present *3-D* information which is viewable in a shared environment. Lastly, overlaying models or information onto consistent tools such as QR cubes enables learning designers to provide learners with vast libraries of digital objects to observe and understand.

MR simulations are harder to define but might be the most relevant to certain vocational education settings. Their hardware requirements are similar to AR simulations, though MR simulations will revolve around the utilisation of specific physical props or features of the physical environment. Therefore, in some settings, the user's interface with the digital environment could be unique to MR. For example, in an aeroplane simulator the user of the simulator does not wear any AR or VR hardware, they immerse themselves in a physical cockpit which also provides digital elements such as virtual windows. The physical elements that are included in MR simulations need to be designed into the simulations, therefore they are regularly a focus of the simulation.

MR simulations allow learners to interact with digital objects or environments in ways that are natural to them, rather than with controllers or other input devices.

VR simulations are those that attempt to immerse the user in a virtual environment. Using current technology, this is often through only visual or a combination of visual and aural simulation. The physical world is left behind in VR; therefore, a regular hardware component of VR simulations is a Head Mounted Display (HMD). Full visual simulation is key to placing the user into a digital reality, aural and haptic simulations are secondary to this.

VR is best used when there is a need to recreate a physical environment. Often, this is due to safety concerns or a lack of physical learning opportunities or resources. VR environments have the potential to offer cognitive learning in the form of knowledge and skills, but also the potential to deliver affective learning through social simulation. There is also the potential for psychomotor learning to be delivered through VR, though enhanced haptic simulation will likely drive this in future.

Below are some examples of how these XR uses might look in context:

- AR or VR might be used to simulate scenes from history. By bringing learners into the historical environment, learners can engage with the scene and possibly retain information more easily due to the use of episodic memory.

- Educators might create physical learning environments that are filled with AR enabled objects. Learners might use smart glasses to view and manipulate digital objects around the room, or the room could be visually redesigned to include elements of the learning –learning about the rainforest with the classroom walls replaced with a jungle scene.

- Vocational skills workshops might include AR information which is overlaid next to machines which detail their safety or operation instructions.

- MR simulators might be used to train operators of machinery, equipment, or vehicles to safely operate them. Pilots are a common example of this – MR training simulators are frequently used to develop their ability to fly planes. What makes their training MR rather than VR is that they will usually have physical or 'real' flight controls in front of them, with the plane's windows being the way that digital simulations are provided to them.

- MR tools might also be used to deliver engaging and informative learning experiences relating to physical objects or systems, such as within the medical field. For example, physical anatomy props combined with digital layers that provide anatomical information as it is relevant, or increased immersion for the learner through the means of simulated body parts or environmental context.

- Emergency services personnel might be trained in VR to prepare for the emotional responses of emergency situations and practice the behaviours needed in these high-pressure situations. For example, paramedics might be able to use VR simulations of accident scenes to practice regulating their emotions and managing those complex situations.

- Therapists in training might use VR to study the behaviours of individuals experiencing psychological distress, or to experience the affective responses that might emerge from complex or stress-inducing interactions.

- Educators might use augmented or virtual reality communications tools to be digitally present with remote or isolated learners.

As XR technologies continue to develop, XR is likely to become more widely used in vocational education. Enabling learners, the opportunities to learn in new and innovative ways, and to develop the skills they need for the jobs of the future.

Benefits of Current XR Technologies

As implied through the example use cases in the section above, XR can benefit education in a range of ways. These technologies can help present information to learners in engaging ways or to enable learners to have multi-sensory learning experiences, to access information in flexible ways, or to learn through experience – this last aspect being of key relevance to vocational education.

BENEFITS TO EDUCATION BEYOND LEARNING

The benefits to learning and learning environments have been focused on in this study, but it should be noted that XR might have benefits to education in a broader sense too. For example, education providers might find utility in using XR technologies to strengthen their educational support functions or other areas. Practitioners might look to how XR is used in other sectors.

The key benefits that are possible when utilising XR for learning are:

- **Increased engagement**: XR can provide immersive and interactive experiences and environments that can make training more engaging and memorable for learners. It can make learners more active participants in learning and stimulate a greater response from learners than traditional education through multisensory simulations. However, engaging students is an ongoing and necessarily reflective process that requires a concerted effort; these technologies are no single solution to learner engagement challenges, but they can support these. It is recommended that these technologies, where applied, are combined with student-centred approaches which enhance student engagement and help achieve optimal learning outcomes (Arghode, Wang, & Lathan, 2017).

- **Greater flexibility for diverse learning needs**: XR technologies allow learning designers a wider range of options for learning delivery. Digital simulations can give flexibility in the ways learners receive, process, and use information, and can also account for individual circumstances and learning needs. For example, learners (in particular neurodiverse learners) can engage with different sensory or experiential components of a simulation that best embed learning for them; geographically distanced or otherwise isolated learners can simulate experiences which may be inaccessible to them in their location; and learning can be self-paced but with appropriate guidance and 'just-in-time' information delivered at the learner's pace.

- **Enhanced knowledge acquisition in some contexts**: Extending from the increased learning engagement and flexibility mentioned above, the digital simulations XR offers allow learners the ability to engage with content in a wider variety of ways. This means that, in some cases, knowledge acquisition may be enhanced using XR technologies. Further, XR technologies can deliver complex learning in ways that are inaccessible to other learning tools. Great examples of this come from the Science, Technology, Engineering, and Mathematics (STEM) areas. Using AR or other XR technologies to model complex problems or phenomena can facilitate learning in ways that some find better than static content or other traditional methods of delivery.

- **Flexible and enhanced skills and competence development**: XR can simulate skills acquisition and competence development, allowing learning designers a wider set of tools to use when considering how to meet learning outcomes. The ways in which XR can provide skills and competence development can also be more diverse than workshop or even some workplace settings. XR can simulate a range of different contexts through which skills can be practiced, more than physical workshops or some workplaces may be able to provide. By doing this, XR allows for these to be developed where opportunities are not available and in simulations that are repeatable, enabling practice. Some development in digital contexts will have a higher degree of portability to real life contexts than others, but XR tools are increasingly becoming more sophisticated in their simulations, therefore making learning more transferrable outside these simulations.

- **Improved safety in training**: XR can be used to create safe and controlled learning environments, which can help to reduce the risk of accidents. This is especially important for training in high-risk industries, such as farming, manufacturing, and construction. Learners have the freedom to fail in simulated environments that they do not in many real situations.

- **Increased training accuracy and consistency**: XR can be used to create highly accurate training simulations which promote the retention of detailed requirements. This is important in the horticulture and agriculture industries, where there is often a need for employees to have a detailed understanding of the tasks they are performing. For example, VR can be used to create simulations of crop growth, so that employees can learn how to care for crops effectively.

- **Reduced resource waste and costs**: XR can help to reduce the resource waste and associated costs of training in vocational education. Traditionally, vocational skills needed to be practiced on real equipment that use real resources. XR technologies enable these equipment and resources to be digital simulated and manipulated, greatly reducing resource costs in some areas. For example, using a plane simulator costs far less than flying an actual plane and has a much lower environmental impact; by practicing how to process an animal carcass in VR the learner does not risk wasting real resources that might otherwise be sold; customer engagement training through digital simulation enables the learner to practice these skills before engaging with real customers that might result in costs to businesses; and fire investigation skills can be taught and practiced without requiring controlled burns of training scenes each time.

- **Improved compliance**: XR can be used to train learners on safety procedures and regulations, which can help to improve compliance. This could be through VR in pre-service training, but AR might also be used to support learners as they practice in real environments. In these examples, pre-service training might be more immersive and practical, or compliance information might be more accessible to a learner when they are operating in a real environment. This is especially important for businesses that operate in regulated industries.

Further to this, XR might have relevance to the career planning and development of learners. By simulating environments, XR enables individuals to perceive and understand occupations, workplaces, or other contexts that they might utilise their skills and knowledge within. This could be of importance to attraction and retention strategies for industries or education institutions. Giving learners and prospective workers the opportunities to engage with these environments more deeply through simulation, or through ‘skills-tasters’, allows them to make more informed decisions about their career pathway.

Challenges with XR in education

The design and implementation of XR is not without its challenges. Some of these considerations for XR include:

- **Relatively high development and implementation costs**: Costs associated with designing XR programmes as well as acquiring the technology to enable them and build the capability to deliver them can be high. These costs are balanced against the benefits of these technologies, though still need to be strongly considered and weighted against learning needs before commissioning XR programmes. In some areas, benefits such as reducing resource waste, improving safety, or enabling practice in areas with few real opportunities will outweigh the costs. Costs with XR programmes are, however, typically higher at inception and design. Acquiring hardware and developing software takes considerable resources, though once complete allows for repeated use at minimal cost[10]. The use of open-source resources and other low-cost technology could however help to reduce costs.

- **Specialised programme design**: XR programmes and products are difficult to design. Specialised skills are needed to develop the software that presents these experiences[11] and to deliver and integrate effective learning with these tools. The latter refers to both the ability to articulate how the XR software should address learning outcomes (alignment with curriculum or learning outcomes) and the ability for educators to effectively administer these experiences in context.

- **Digital simulations cannot replace the real world… yet**: While XR, and particularly VR, simulations are becoming more sophisticated, it is impossible at this time to simulate *all* aspects of a given environment. This means that real contexts are still necessary for learners to practice and acquire competence within. XR can be immersive at the moment, though excels specifically in transferring learning through sight and sound. It is possible to deliver lower-level psychomotor learning in current XR environments, though haptic technology needs to develop further before more advanced psychomotor skills can be developed effectively Also, XR technologies need to improve their ability to simulate physical laws of the real world (Paszkiewicz, et al., 2021). Further to this, XR experiences need to further develop their ability to simulate social experiences.

- **Accessibility**: Flexibility and accessibility are benefits to XR, but they are also challenges. While some diverse learners might prefer or respond better to XR experiences than to traditional learning, improving outcomes in some areas, there are also groups who may have less ability to use or access XR. For example, people with disabilities may be less able to use XR hardware and, without institutional provision, the costs of XR hardware may be prohibitive.

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[10] It should also be noted that XR development and implementation costs should continue to reduce over time. Also, consideration should be given to 'minimum viable' experiences and technologies. The array of XR technologies that exist vary greatly in price, though the cheaper tools and hardware can effectively meet a range of needs.

[11] Ashtari et al. provide an overview of selected experiences, challenges, and opportunities for those developing AR and VR content (Ashtari, Bunt, McGrenere, Nebeling, & Chilana, 2020).

- **Health and Safety**: Some users of VR environments can experience issues such as motion sickness or eye strain. Design techniques exist to mitigate these health issues, though many still experience these.

A New Zealand based review of VR for educational purposes from 2017 also identified the following issues within the literature it analysed (Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2017):

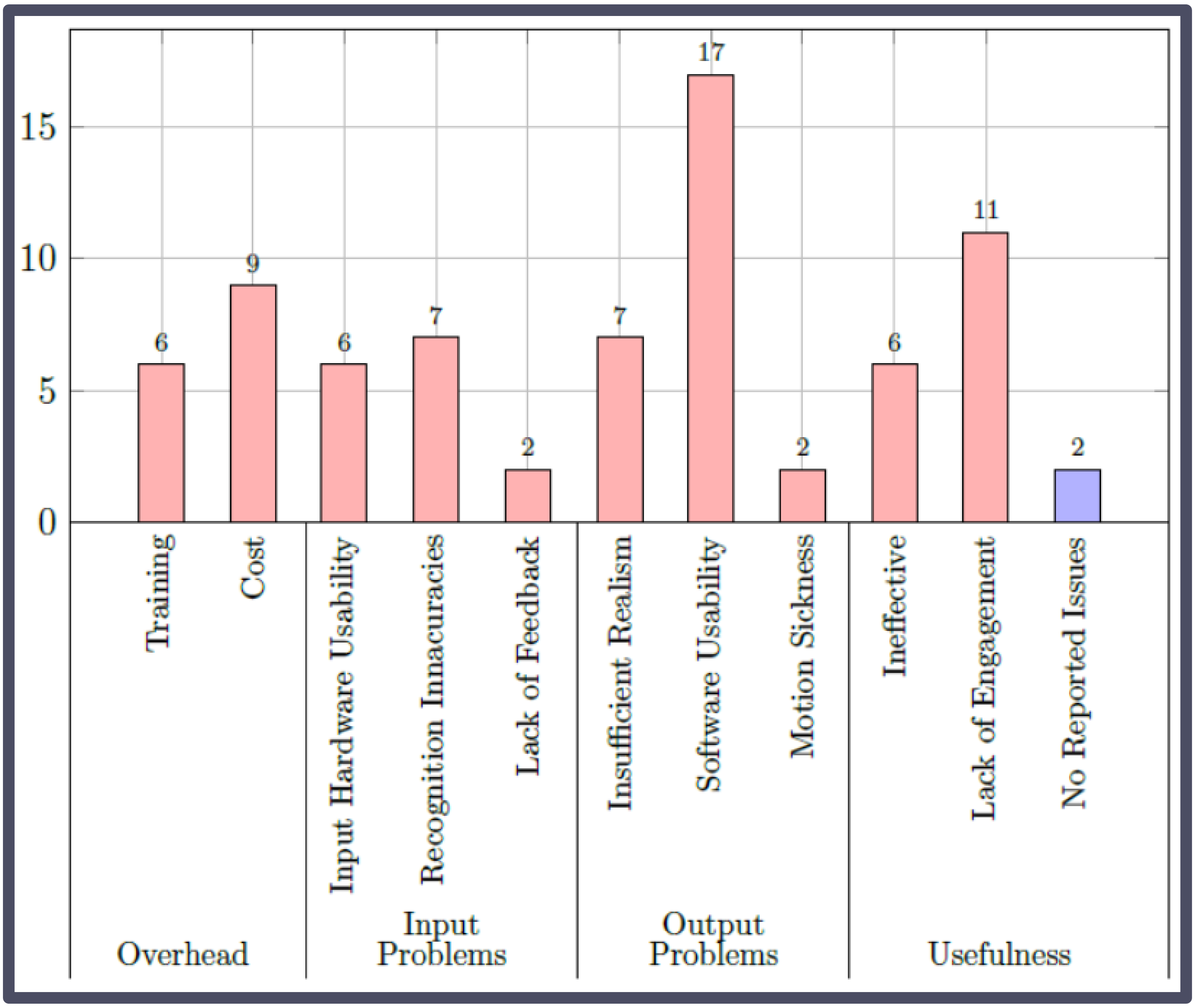

Figure 2: Issues and limitations of VR in education, identified through thematic analysis of 35 papers on the topic. Source: (Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2017)

From this analysis, albeit of a small number of studies. software usability and lack of engagement with the technology stand out as common issues. The authors suggest that the software usability issues might partly be explained by limited user knowledge, but that these also had a component of poor software design. The limited learner engagement reported in some of the studies was commonly described as “boredom”, though the authors suggest that it is unlikely such an effect is the result of the technology itself, but rather a symptom of the various other issues seen in the graph in combination. If the learner’s inputs to the technology are not recognized well and the output they are receiving from the technology is poor, they are more likely to disengage. This points again to the importance of effective simulation and programme design to ensure experiences are engaging.

Examples of XR in Action

Below are some examples of how XR can be, or are being, used for educational, training, or production purposes:

- The medical sector uses XR to support the training of medical students. Examples include medical students using these technologies to practice procedures virtually to prepare them for real-life practice and procedures.

- Otago polytechnic has partnered with international company Pearson to provide Hololenses to nursing students which allows them to view 3D images of the body, including organs, as well as assess relatively common conditions that they might not experience on clinical placements.

- At the University of Central Florida, aspiring teachers learn through TeachLive, an MR simulation that helps student teachers practice managing tricky situations before they enter real classrooms.

- Walmart uses virtual reality to train their staff in multiple aspects, for example preparing employees for Black Friday sale events and training workers on how to respond to angry customers or upskilling employees for middle management positions.

- The manufacturing sector is using VR to build comprehensive digital twins of real-world environments. Major firms such as Siemens, NVIDIA, Unity, and General Electric have already developed intricate digital twins of manufacturing plants to brainstorm ideas, monitor on-site processes, and boost quality control protocols.

- The hospitality industry can use XR to support their food production processes virtually or simulating real-life scenarios for training staff. Examples include how to deal with difficult customers or different customer service scenarios or to education new staff on the restaurant menu or how the food is produced and cooked.

- MR can be used to support proper hygiene in food facilities for example using Hololens to undertake or teach people how to carry out inspections. A HoloLens can add a digital layer to any form of maintenance or service like a hygiene inspection and highlight any critical areas to ensure the worker covers all important places and have taken all the necessary steps.

- XR can provide virtual field trips for students, including to locations that are too far to travel to or dangerous to access. You can also explore complex scientific topics in detail, like manipulating a 3-D model of a molecule.

Summary

There are lots of examples of how XR is being used in the education sector. The technology is well suited for use in vocational education as it can simulate real working environments. Furthermore, it can engage people in learning while providing a safe learning environment that allows for mistakes and repetition, support diverse learning requirements, potentially enhance knowledge acquisition, and can help with career planning and decision making.

There are still some disadvantages associated with the use of XR technology, however. When considering the use of XR in the workplace, barriers include high costs associated with designing and delivering content alongside the purchasing of equipment, and useability. XR technology is still evolving and will likely see the technology decrease in costs and become easier to access and use. Advances in XR may also see the development of systems that can provide complete sensory simulations perhaps leading to a richer learning experience. This combined with cheaper implementation costs could lead to a greater utilisation of the technology for education purposes and for learning in the workplace.

ARTIFICIAL INTELLIGENCE IN EDUCATION

Uses and Benefits of AI in Education

AI in Education – Current and Future Uses

Artificial intelligence is a transformative technology that will likely change the way many sectors, including education, operate. It is challenging to outline AI's potential uses within education as its impacts are likely to be diverse and wide-ranging. The use of AI as a mainstream tool within education is also still in its infancy. As the technology advances and practitioners become more familiar and adept at using it, however, it is likely to gain more prominence within the education sector.

Various researchers have attempted to categorise Artificial Intelligence (AI) in education. Some consider applications to be learner-facing, teacher-facing, or system-facing (Baker, Smith, & Anissa, 2019), whereas others refine these into learning-oriented, institutional supports, and policy-oriented applications (Srinivasan, 2022). From these various categorisations, AI's clearest two uses are for *learning* and the *facilitation of learning*.[12]

A systematic review of AI studies within higher education until the end of 2022 identified the following research focuses for AI – providing a proxy measure for how professionals are applying these tools (Crompton & Burke, 2023):

- **Assessment and Evaluation**, the most commonly studied area, including:
    - Automatic assessment
    - Generating tests
    - Feedback, being real time and formative
    - Reviewing Online Activities such as learner interactions or reflections
    - Evaluating Educational Resources

- **Predicting**, including systems to predict learner outcomes, attitudes, risks, and development pathways.

[12] It is also useful to note that many studies of AI in education focus on higher education, rather than vocational education.

- **AI Assistants**, including a range of chatbots, intelligent tutors, expert systems, or similar, for a range of purposes.

- **Intelligent Tutoring Systems**, those which customise educational activities and strategies based on learner characteristics and needs.

- **Managing Student Learning**, such as systems to support administrators or educators to manage learning by providing, organising, or analysing data.

Further to these areas, in late 2022 breakthroughs in the development of Generative AI occurred and brought in a new range of considerations for AI in education. AI within education had previously been relegated to back-end processes and the support of learning rather than any significant utilisation within the learning environment. Now, Generative AI tools have pulled AI to the forefront of education conversations. This is likely due, in part, to many Generative AI software publishers having free and open products for the public to utilise, enabling a wider audience to experiment with these tools. It is also, however, due to the more mainstream potential that Generative AI tools offer. Rather than highly specific functions that other AI might offer, Generative AI tools offer a broad function – content generation – within which users can experiment with and identify their own use cases for.

Several groups have rushed to consider these possibilities which are now being mainstreamed in various sectors. A Kasneci et al. analysis suggests the following potential uses of Generative AI, specifically text content generation, for learning and teaching (Kasneci, et al., 2023)[13]:

- **Opportunities for learning:**
  - The development of reading and writing skills, as well as writing style and critical thinking skills, for elementary school students.
  - Support the learning of languages and writing styles for various subjects for middle and high school students.
  - Support with research and writing tasks, as well as the development of critical thinking and problem-solving skills in university students.
  - Facilitate group discussions and debates by providing structure, real-time feedback, and guidance during the discussion.
  - Empower learners with disabilities with speech-to-text or text-to-speech solutions; adaptive writing, translating, or highlighting of content; or other methods.
  - Support professional training in areas such as programming, report writing, project management, et cetera.
- **Opportunities for teaching:**
  - Support the development of inclusive lesson plans and activities.
  - Support the teaching of languages through adaptive feedback.
  - Support educators to complete research or writing tasks.
  - Support professional development of educators through provision of summarisation or explanation of development areas.

[13] These opportunities represent the potential opportunities for Generative AI that generate text-based content, though many of these points are relevant to other types of content generation too. Research efforts are being focused on text-generating Generative AI currently because these tools are, so far, more sophisticated than image, video, or audio generation tools. Therefore, they are more immediately usable.

- Support the grading of written work by highlighting possible themes or gaps in the text.

- **Other applications for teaching may include:**
    - Draft, enhance curriculum; lesson plans; authentic assessment rubrics.
    - Create software programs to assess, measure and provide timely feedback for project artifacts.
    - Foster a dialogue with students around AI.
    - Scaffold the learning process.
    - Encourage active engagement and critical thinking.
    - Incorporate alternative assessments.

It is hard to predict all future use cases for AI in education; there are many and they are limited mostly by imagination. As more AI tools, both General AI and Generative AI, become available and incorporated into practice, further use cases will certainly emerge. There is enormous potential for these tools to transform the ways in which we live our lives and the ways in which we learn, but there are also social and moral boundaries, among others, that need to be clarified as we integrate these into the education space.

Benefits of AI to Education

Key themes from these use cases suggest the following benefits of AI in Education:

- **Adaptive design and delivery** – Artificial intelligence allows for cognitive tasks to be outsourced, leading to efficiencies. The key efficiency within education relates to the flexible design and provision of programmes. Rather than 'one-size-fit-most' delivery models, AI may be used to efficiently design programmes or adapt delivery of these programmes to meet cohort or individual needs; to predict learner performance and proactively identify or address gaps; or to assist educational support functions to plan and deliver services.

- **Idea generation** - Input specific learning outcomes. Generative AI can assist in generating ideas for roleplays, debates, thought experiments and other interactive activities. This, in turn, can stimulate student engagement and critical thinking.

- **Scenario Creation** - Create realistic and relevant scenarios for role plays or thought experiments using Generative AI. Faculty can provide the model with the context, topic, or theme you want to explore, and it can offer suggestions and descriptions, or even help create dialogues for the given scenario.

- **Teaching strategies** - Use Generative AI to provide answers to questions related to specific teaching strategies. If you have queries about how to structure a debate, conduct a think-pair-share activity, or implement other active learning techniques effectively, Generative AI can offer insights, strategies, and best practices to consider.

- **Feedback** - Generative AI can provide feedback and evaluation on student work or responses, particularly in written form. You can simulate a role-play or debate scenario with the model, and it can review and analyse the students' written contributions, providing constructive feedback and suggestions for improvement.

- **Supporting research and innovation** - Researchers can use AI to analyse and synthesise large amounts of data, identify patterns and trends, as well as explore new lines of inquiry and make connections that would be difficult using more traditional means of research.

Challenges with AI in Education

The rise of AI within the public consciousness has come with challenges and nowhere is this more evident than in the education sector. Traditionally, educators tend to be keen adopters of new technologies but certainly not without controversy and naysayers.

The calculator in the 1970s created debate within schools on whether their use in the classroom amounted to 'cheating' and sparked concerns that students would become too reliant on them at the expense of understanding the underlying methods for calculation. However, the education sector adapted and now calculators are an intrinsic part of education (Ng'andu, 2023).

The similar arguments are now being had regarding the use of AI in education. Schools and higher learning institutes around the world are grappling with the idea of how AI should be used within education. Concerns about academic integrity and students cheating by using Generative AI to write essays or complete homework is at the forefront of educator's anxieties. Ultimately, however, AI is likely here to stay and will become an innate part of learning. Educators will need to consider how to use AI as a legitimate learning support tool. The challenge, therefore, becomes how best to overcome these apprehensions and issues.

The following list outlines some examples of the concerns, considerations, or challenges to the implementation of AI in education:

- **Educator overreliance:** Educators may shift from resistance toward AI to overreliance (Zhai, et al., 2021). AI tools (Generative AI being of particular relevance at the moment) are not without their issues to validity. Without the critical interpretation and contextualisation of current AI tool outputs, educators are at risk of promoting or delivering invalid, unjust, or incorrect information that learners. While AI cannot reliably give correct or accurate outputs, and probably still after they have been judged capable of this, educators should critically reflect about the ways in which they use these tools.

- **Ethical issues – data use and privacy:** These include concerns about how AI uses data to inform its models, and well as how user data might be incorporated into AI models, particularly individual learner data (Zhai, et al., 2021). The ways in which learner data is used to train, inform, or feed into AI tools is unclear. Justified concerns are being raised about the potential for learner data to be inappropriately utilised by AI tool developers or their models.

- **Intellectual property:** Currently, Generative AI models utilise publicly accessible data to inform their models and, therefore, their model's outputs. AI generated content based on existing text, images, code, or data can result in disputes over ownership, with some content that the AI is 'trained' on being protected under law via patents, copyright, and trademarks. How much the Generative AI's output 'is' the original owners' work and how much is 'inspired' by the original owners' work is unclear and this issue needs to be resolved. Consideration is ongoing within legal parameters regarding intellectual property and AI. There are also questions concerning intellectual rights of the AI itself. As AI generates more content, at which point does that content become 'original' and therefore who/what owns the rights to that 'new' content? (Ghanghash, 2023)

- **Hallucinations and false accounts:** AI hallucination is when a Generative AI generates false information but presents it as fact. These can range from minor inconsistencies and nonsensical information to irrelevant or completely inaccurate information. AI hallucinations can be caused by biased or poor training data, a lack of context provided by the user, or insufficient programming in the model that keeps it from correctly interpreting information. This is particularly concerning with text generation.

- **Identifying appropriate, relevant, and meaningful generative AI for educational delivery:** Identification and use of appropriate AI models to support education delivery aligned to best pedagogical practice. For example, using AI to target curriculum co-design, generate educational materials, provide virtual AI driven tutors/assistants, or produce individualised lessons and resources for learners (Nah, Zheng, Cai, Siau, & Chen, 2023). As with all educational tools and techniques, educators should carefully assess the benefits and risks of these before implementing them and should always keep educational quality and experience at the heart of these evaluations.

- **Resistance to change:** There is some resistance to AI stemming from apprehension about what these new technologies mean for society, individual industries, and for people's jobs. In education, AI is viewed by some as a threat to traditional methods of learning. Some are concerned that learners may use the technology to cheat or commit plagiarism, thereby threatening academy integrity. Ultimately, however, this resistance may prove futile as, like any other educational tool, AI has the potential to enhance and supplement teaching and learning (Nah, Zheng, Cai, Siau, & Chen, 2023).

Examples of AI in Education

While the use of AI has direct application in classroom-based education, there are fewer examples of how AI can be used to train people 'on the job'. Examples of classroom-based AI education include personalised tutors and coaches, AI assisted assessments to identify skill gaps, and personalised learning experiences and curriculum. These examples are less apparent in vocational education.

AI technology is mostly being used in the Food and Fibre sector as a production or insights tool. It is used to help anticipate weather events, manage crops and pastures, identify the health of animals, value chain planning, logistics and supply or to automate physically demanding and time-consuming tasks. In this regard, AI will eventually emerge in vocational education through industry-specified skill standards – the use of AI tools will be something that industry requires of its learners and apprentices. There are fewer concrete instances of where AI is being directly used for training and skill development; though, below are a few examples:

- The University of Auckland has created virtual patients using AI to simulate interactions and teach medical students how to engage and empathise with patients. The AI virtual patients will be able to express emotions and react to and ask questions. This enables students to learn how to talk to patients in various emotional states and who come from different backgrounds (University of Auckland, 2022).

- Aimer is a company based in Hamilton that is using an AI-driven digital assistant to help farmers best manage their pasture and paddocks (Aimer Farming, 2023). The technology can identify and measure the needs individual pastures and relay data back to the farmer. The technology can be used by those new to farming and with limited or no experience, cutting out the need to train farm staff and shortening the learning timeframe.

- The DeHaat Farmer App developed in India is designed to assist farmers with their day-to-day farming needs (DeHaat, 2023). Using AI, it provides up to date data on areas like soil testing, pest control and crop health, flood, and drought prediction. It also provides access to farming experts so farms can learn more about farming techniques and gain faster solutions to farming problems.

- AI powered learning assistants have been proposed in some areas for rural or geographically remote learners and employees, of which many food and fibre sector learners are categorised as. Where there is less capacity to provide human facilitators, AI powered tutors or learning assistants could support these vocational learners.

Summary

As discussed, the most common use of AI in the education sector is as a classroom-based tool or as a tool for supporting productivity in the workplace. There are fewer examples where AI is being used as an education tool for on the job learning.

There is little doubt that AI will change the workplace much in the same way the internet or computer did, creating significant efficiencies in the way people go about their everyday work. Whether AI will be used as widely to facilitate vocational education learning in the same way as VR or GAM remains to be seen. Certainly, there are advantages for some industries that require training tools that simulate environments or interactions to create safe or realistic training (the medical industry for example). AI within the Food and Fibre sector is currently focussed on its ability to support productivity and to provide insights rather than for training and development. This doesn't mean that AI can't be used in vocational education. It is possible as the technology evolves, and more people become aware of how AI can be used in workplace training that necessity, imagination and innovation will drive the development of AI as a training tool.

Until then, academics and practitioners will continue to debate and consider the challenges of AI and how to overcome these. Further guidance on the use of AI, particularly new Generate AI tools, in educational settings is provided by the New Zealand Ministry of Education (New Zealand Ministry of Education, 2023) and the Organisation for Economic Co-operation and Development (OECD, 2023).

DISCUSSION

Considerations for the NZ food and fibre sector

Emerging technologies such as Gamification (GAM), Extended Reality (XR), and Artificial Intelligence (AI) have the potential to revolutionise how vocational training is undertaken in New Zealand and around the world. It is important that the Food and Fibre sector actively engages with these technologies now to ensure we are not left behind the rest of the world.

It is, therefore, vital that we gain a clear understanding about how to use these technologies to enhance training and support people to be 'work ready' while helping employers to attract, retain, and upskill staff.

This paper has outlined some of the benefits and challenges that come with each technology and how they are currently being used to engage people in training and education. The Food and Fibre sector should consider these when determining how to best utilise these technologies.

The sector is currently using these technologies to make tasks easier or more efficient; their use as training tools, however, is mixed. Gamification and XR are more widely used for education purposes with multiple examples available. AI has fewer training examples. This may be due to AI being relatively new and the understanding and potential application of it for training is still evolving.

The following is a brief outline of some of the wider issues associated with the use of the emerging technologies that the Food and Fibre sector may wish to consider when looking at the implementation of these technologies in general across the industry.

Addressing Workforce Shortages

One of the biggest issues facing the Food and Fibre sector is workforce shortages. These shortages impact production capacity and highlight the need for more innovative workforce solutions and improved labour attraction and retention strategies.

These technologies are one means through which the sector can address the current labour shortages. Technology is a considerable draw card to the industry by promoting Food and Fibre jobs as more than just milking cows or picking fruit. It demonstrates that the industry is an exciting cutting-edge place to be with opportunities to work in new and innovative ways. Highlighting the use of these technologies may draw people to the industry and generate more interest in Food and Fibre as a career pathway.

Risk and Fear

One of the biggest concerns about the use of these technologies, especially AI, is that wide-spread use could lead to job displacement or 'technological unemployment'. As AI-powered machines become more sophisticated and capable, they could automate many of the tasks currently performed by human workers. This could lead to unemployment in the sector, particularly among low-skilled workers. However, having technology automated machinery to carry out labour intensive work creates an opportunity to free up workers to focus on other activities that require human expertise, thus maintaining the workforce or creating new jobs entirely.

Fear of the unknown is potential issue for some employers as new technologies bring new ways of working. Employers who are used to traditional methods of cultivation and production may be resistant to introducing these technologies into their workplaces. However, the Food and Fibre sector have always been quick to adopt new methods for working and the adoption of new technology can have a viral effect. When one business shows successful outcomes using new technology this often inspires others to follow suit.

Ultimately, however, workplaces and workers adapt, and new opportunities are created because of these changes. To remain competitive, the Food and Fibre sector will need to embrace these technologies and use them for the benefit of the sector.

Legislation and Policy Decisions

As noted, the pace of technology changes has been very quick and as such the potential implications for society haven't yet been fully realised. This is particularly true for AI. The sudden emergence of AI in the public consciousness has resulted in governments racing to catch up and address the implications of these technologies.

Worldwide, governments are working with technology experts to assess the potential impact of these technologies. They are creating policies, guidelines, or frameworks that support the use of AI while safeguarding against perceived risks.

New Zealand doesn't currently have a national strategy or coordinated approach to AI. However, New Zealand policy makers are assessing AI policies and considering how to apply them to a New Zealand context and individual organisations are creating their own policies when it comes to the use of emerging technologies.

Much of the need for legislating these technologies comes from the requirement to protect against 'bad actors'. Individuals, organisations, or entities that exploit AI and XR technology to manipulate or steal data, spread disinformation, commit fraud, undertake cyberattacks and breach privacy. Addressing these issues requires governments and organisations to ensure there is legislation, regulations, and safeguards in place to prevent misuse.

Ethical Considerations

While these technologies have the potential to transform the workplace and day to day activities, they also come with important ethical questions. The rapid development of these technologies means considering issues like privacy, intellectual property rights, bias, consent, and transparency are paramount. The technologies, while advanced, are still subject to their creators' fallibilities and to the quality of the data used at input. AI generated hallucinations do occur, and these technologies can be subject to their creators and users own subjective bias.

Consequently, when implementing and developing programmes using these technologies, accountability, inclusivity, and risk mitigation needs to be considered, to ensure the technology is being used responsibly and in a manner that respects individual rights.

Furthermore, an important consideration for a New Zealand context is Māori data sovereignty. Any programmes developed need to ensure that Māori data is used in a way that respects the rights and autonomy of Māori and upholds and protects Mātauranga Māori as well as the unique cultural, historical, and ecological position Māori hold.

Conclusions

If the Food and Fibre sector is to remain competitive and future focussed, it is important that industry, employers, and employees embrace these new and emerging technologies in a way that adds value to their workplaces.

To this end, the potential applications of Gamification (GAM), Extended Reality (XR), and Artificial Intelligence (AI) in the education and vocational training sectors offer exciting opportunities for increasing production and enhancing learning experiences. However, these technologies should be thoughtfully considered and developed from an evidence-base before implementation.

GAM, while promising, should be judiciously applied, considering its suitability for different learning contexts and the alignment with clear learning objectives to foster motivation.

XR technology, with its ability to simulate real working environments, holds significant promise in vocational education. It provides safe learning environments, supports diverse learning requirements, and enhances knowledge acquisition, though it comes with initial barriers like cost and usability. As XR technology continues to evolve and become more accessible, its potential for education and workforce training will likely grow.

AI, while currently more focused on classroom-based and productivity support, has the potential to revolutionise vocational education. As AI technology advances, it may find wider applications in on-the-job learning, particularly in industries requiring realistic training environments. While challenges and debates remain, the adaptability and innovation of AI for vocational training may become a driving force for its integration into the learning landscape.

In this ever-evolving educational landscape, the prudent use of these technologies, aligned with evidence-based practices and a deep understanding of the diverse needs of learners, will determine their effectiveness in enhancing education and vocational training. The future holds significant promise for the fusion of technology and education, where smart, informed, and thoughtful integration will lead to improved learning outcomes and a workforce better prepared for the challenges of tomorrow.

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