Source: Pinerest, pngtree

IIAD

A **Technological** and **Pedagogical** Analysis of **Immersive Reality** (Augmented/Virtual Reality) for the **Design of Educational Content**

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Introduction

Education today is impossible to think about without technology. Even though technology does tend to become invisible in the traditional classroom, blackboards and chalk is also technology. In the last few years, it has become much more prevalent in the form of interactive boards, computer classes and language labs. Due to covid-19 and distance learning, technology it has come to the forefront of education, with online collaboration tools and other technology.

Immersive reality has also become a technology that has been studied and implemented in the last few years in this sector. We have seen a rise in books, research and case studies written on this topic especially since 2019. Although many books discuss the technology, its needs in education and various application of it in the past few years; we haven't come across any framework on how to turn a regular curriculum into an immersive learning curriculum. When we say immersive technology, we refer to Virtual, Augmented and Mixed Reality technology.

In the next few sections, our aim is to establish design methodology and a framework by which educational content of any discipline can be turned into immersive learning content.

But to go to school in a summer morn, –
O it drives all joy away!
Under a cruel eye outworn,
The little ones spend the day
'n sighing and dismay.

Willian Blake- "The Schoolboy"

Immersive Reality in Education

The Pandemic boosted Immersive Reality (IR) technology in various domains. It has come a long way, from a small technology to a growing trend across multiple industries. (FORBES, 14th Sep 2021) Education, as an industry has also seen some significant study and development in this domain of technology.

Virtual reality (VR) is a technology that has recently arrived at frontline as one of the core features of many industries including education. (Virvou & Katsionis, 2008). Virtual reality can be a useful tool in creating innovative and educational experiences, helping students gain knowledge and improve their skillset (Ardiny & Khanmirza, 2018;Mikolajczyk, 2019). It provides an opportunity for students and teachers to experience, as well as interact, with various learning phenomena, in a way they wouldn't be able to in the real world. (Shin, 2017; Vesisenaho et al., 2019).

fig 1.1: Immersive reality.
Source: https://coreaxis.com/

TPACK: Technological, Pedagogical and Content Knowledge. A framework created by Punya Mishra in 2006 as an extension to the work of Shulman in 1980. According to the framework a teacher must not only possess knowledge on the three fields- Technology, Pedagogy and Content; and also the overlap between them, such as, technology-pedagogy, technology-content, pedagogy content and technology-pedagogy.

Technology in Education- The TPACK Framework

Traditional classrooms use a variety of technologies, from textbooks to projectors, from typewriters in English to the periodic table on the walls of chemistry classroom. (Mishra, 2006). However recently, technology has emerged to the forefront of education. Nowadays online collaboration, interactive projections and other technologies are used constantly to improve the teaching process. *"The rapid changes in technology has completely changed education and the classroom." (Kaliisa, Edward, & Julia, 2019)*

fig 2.1: Technology in education

While discussing educational instruction and the process of teaching, it is not enough to consider disciplinary and pedagogical knowledge separate from technology. Teaching is a complex cognitive skill activity that takes place in a multilayered environment (Leinhardt & Greeno, 1986) and teaching is dependent on access to *"highly organized systems of knowledge" (Glaser, 1984).*

As outlined by Punya Mishra (2006) in his paper, ***"Technological-Pedagogical-Content** Knowledge"* is a framework for how knowledge about each of these three domains, and understanding about their interplay with each other is important for any teacher for successful instruction.

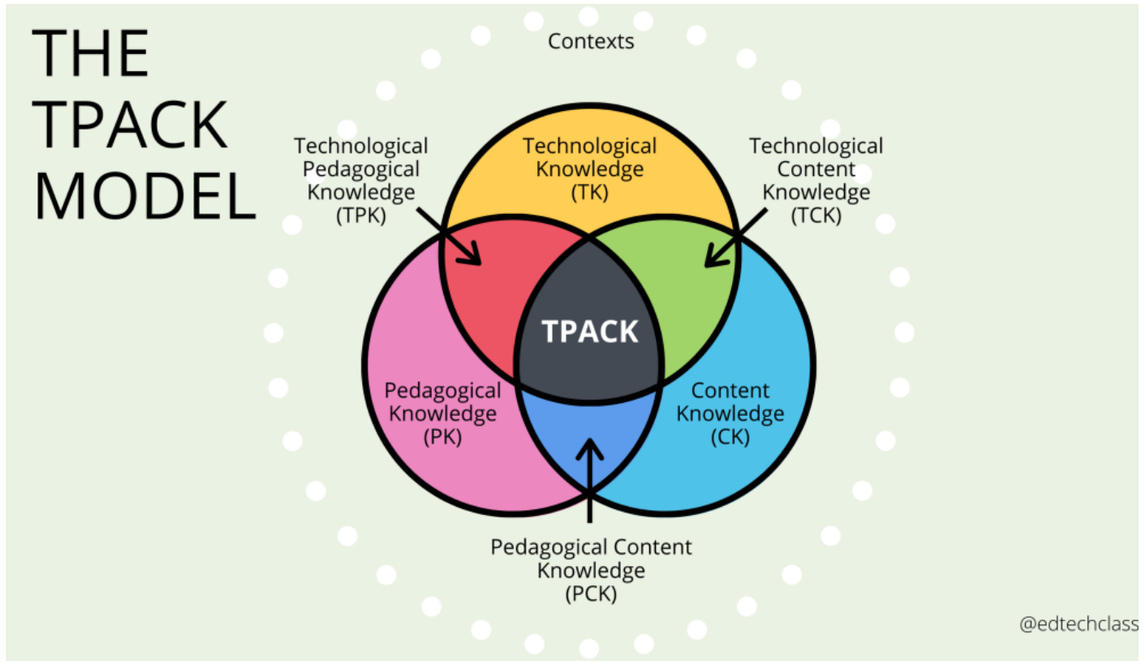


fig 2.2: The TPaCK model.
Source: https://myedtechclassroom.files.wordpress.com/2021/06/tpack.png?w=1024

Creative use of the TPACK framework

The TPACK framework defines that a teacher requires knowledge in several domains for proper instruction in any discipline. However, when analysing any technology such as Immersive Reality in the domain of education, the TPACK framework allows us to understand how it corresponds to pedagogical practices and disciplinary content. Thus giving us an understanding of how exactly the technology can improve both the teaching and learning process. Furthermore it allows us to understand how educational content can be designed for the same.

In this paper we suggest that the framework can be used to analyse any technology; and the paradigm can be applied in the design of educational material and content. Understanding Technology, Pedagogy and the Content; and also the relationships between them can help design effective educational material in any discipline with any technology.

fig 4.1 VR in the Classroom.
Source:. https://s3-us-east-2.amazonaws.com/maryville/wp-content/uploads/2019/05/21115045/student-wearing-vr-headset-500x332.jpg

fig 4.2 VR in the Classroom.
Source:.https://edtechmagazine.com/k12/sites/edtechmagazine.com.k12/files/styles/cdw_hero/public/articles/

The next section will discuss mainly the Technology-Pedagogy and Technology-Content overlaps. The Pedagogy-Content overlap required detailed disciplinary knowledge and is a subject which is out of the scope of this paper; which only deals with Technology at its forefront.

AR/VR in Education- its needs and its benefits

"Motivation plays a very important, and possibly the most important, part in the learning process. VR can increase engagement, retention, and desire to learn." (Sushma Sharma, Veative)
Veative prescribes to Daniel Pink's theory of motivation, (1971) of which the key factors are-

1. Personal relevance (Purpose)
2. Choice and control (Autonomy)
3. Mastery is within reach

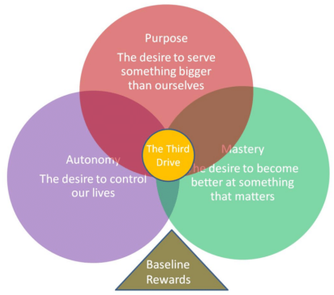


fig 5.1 Pink's Theory of Motivation.
Source: https://www.conversion-uplift.co.uk/glossary-of-conversion-marketing/motivation/

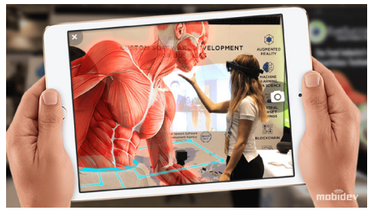
While discussing Immersive Technology there are three specific types of technology that can be beneficial in Education. (Donally, 2021)
Virtual Reality (VR): Using VR the classroom can teleport anywhere—to the Taj Mahal or the first moments of the Big Banh. Using a VR headset or mobile device one can visit a virtual world of any environment in the universe or time in history
Augmented Reality (AR): Using this technology, students can view the real world with a digital layer on top. Thus allowing them to bring the solar system or 3D animated animals in their classroom to study. And lastly,
Mixed Reality: A type of Augmented reality in which digital objects can interact with real-world ones. For example: placing various digital biological specimens on your desk and dissecting them. (diagram)

"Educators face difficulty today, due to of the world moving from the Information Age to the Experience Age" (Wadhera, 2016). Students can be resigned and disinterested in the topic (Capps and Crawford, 2013) and don't seem to understand how the knowledge gained may be used in the real world. (Gee, 2009). **AR/VR Technology offers affordances that overlap with pedagogical theories and ideas which attempt to overcome such problems of our age**. This makes the technology extremely promising in the field of Education.

With Facebook recently releasing their meta-verse, AR/VR in our everyday lives became mucwwh more than a pipe dream. Many such big tech companies now plan on investing heavily in this technology and bringing it to various areas of people's lives, including education!

fig 3.1: Types of Immersive Content.
Source: https://summalinguae.com/language-technology/international-virtual-reality-market/
https://mobidev.biz/blog/augmented-reality-future-trends-2018-2020
https://augray.com/blog/what-is-mixed-reality/

Virtual Reality



Augmented Reality

Mixed Reality

Pedagogical Ideas

Multimedia

Multimedia refers to a mix of various mediums of Educational Instruction like text, audio, video etc.

Multimedia can have potential roles in enhancing learning. (Al Hamdani, 2008) The Idea of Multimedia Education stems from the concept of Learning Styles, which states, *"Students vary in terms of the most beneficial mode of learning for them." (Pashler, McDaniel, Rohrer, Bjork, 2008).* Multimedia enables us to provide a way by which learners can experience their subject in a deeper manner. Which mean students are given simultaneous access to various different media rather than sequentially.

fig 6.1 Multimedia. Source: https://image.shutterstock.com/image-vector/banner-multimedia-concept-vector-icons-260nw-677306068.jpg

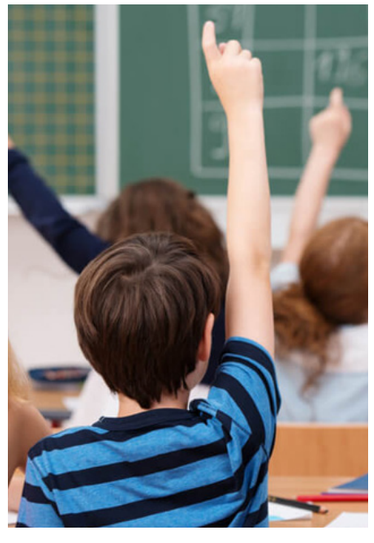
Engagement

The Pedagogical theory of Engagement was introduced by Edgerton, R. in 2001. Pascarella and Terenzini's summary of twenty years of research on the impact college has on student development further supports the importance of student engagement: They suggest that a student's knowledge acquisition and cognitive development was direct related to their level of involvement of engagement in academic work of academic experiences. They also suggested that their engagement also influenced their cognitive and psychological change.

IR technology shows promise in allowing students to engage with the educational material.(Walker, Don 2017) Muti User Virtual Environment (MUVE) immerse students in engaging virtual worlds to perform task and interact with complex scenarios. For example: EcoMUVE, is a desktop based application develped by the Harvard School of Education which uses immersive virtual environments to teach middle school students about ecosystems and causal patterns. The EcoMUVE environment is inquiry based, where students are able to engage with different parts of the environment and collect information.

"Learning 'about' things does not enable students to acquire the abilities and understanding they will need for the twenty-first century. We need new pedagogies of engagement that will turn out the kinds of resourceful, engaged workers and citizens..." (Edgerton, 2001)

fig 6.2 Engaged Students. Source: https://assets-homepages-learning.3plearning.net/wp-content/uploads/2020/06/blog-20-student-engagement-strategies-captivating-classroom.png



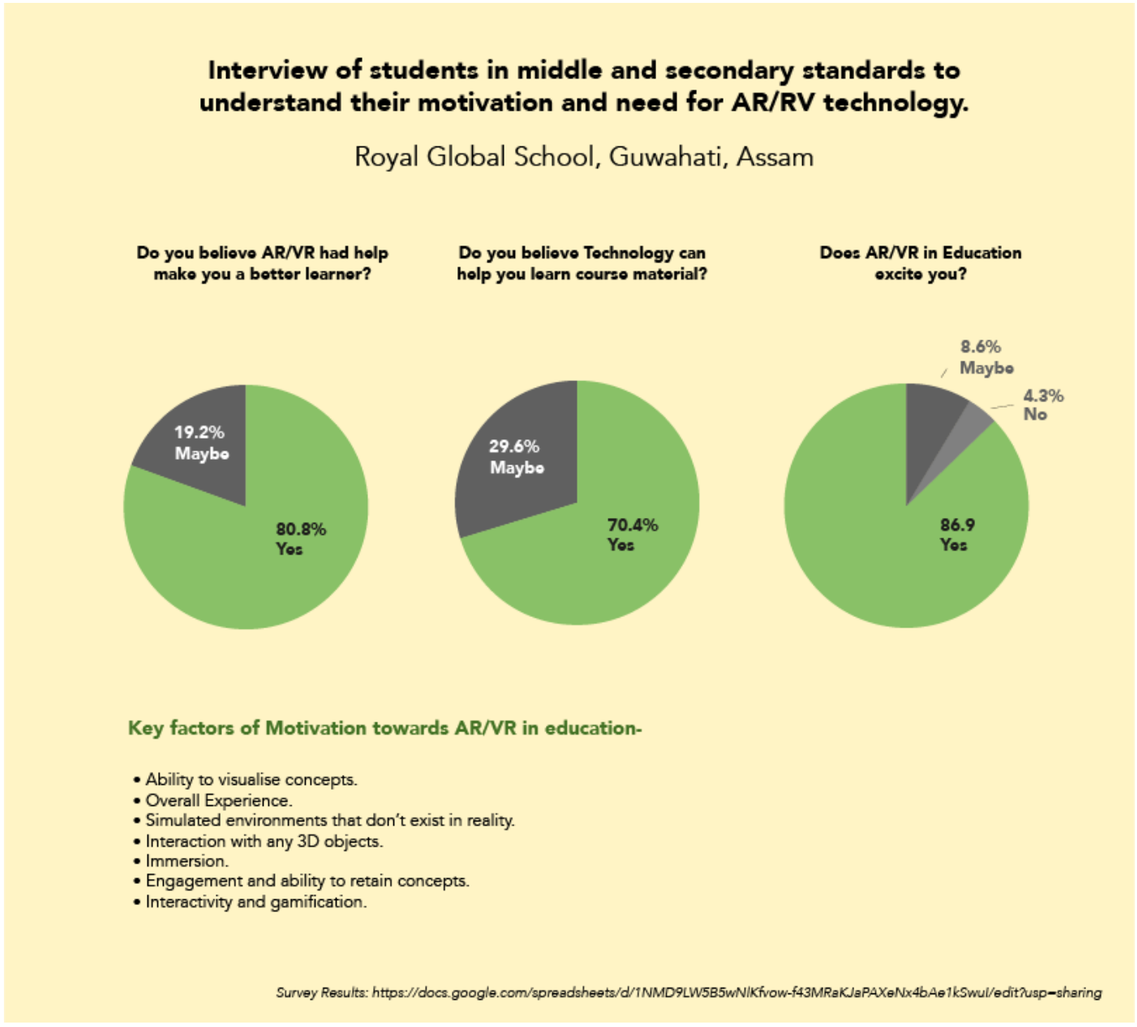


fig 6.3 Primary Research

Primary Research conducted in a CBSE school in India further strengthens the possibility of Engagement if AR/VR is used in school. The study was conducted in Royal Global School, situated in Guwahati, Assam, India. The study consisted of 27 participants who were asked specific questions of AR/VR and the use of technology in the classroom.

Interviiew Responses- https://docs.google.com/spreadsheets/d/1NMD9LW5B5wNlKfvow-f43MRaKJaPAXeNx4bAe1kSwuI/edit?usp=sharing

Situated Learning

Situated Learning is a pedagogical theory introduced by Lave and Wegner in their book in 1991. Situated learning theory holds that effective education requires learning that takes place in *"authentic contexts of application."*
Learners should be involved in authentic settings of daily practice, applying knowledge, and making use of artefacts in productive but low-risk ways. This usually requires social interaction and collaboration within the disciplinary community, however the student gradually moves away from this community to become more independent. (Lave & Wenger, 1991). *"Situated learning takes place in a similar environment to which it is later applied." (Anderson, 2004)*
AR/VR technology is able to take advantage of this powerful pedagogical concept, and create learning environments which are authentic to real world contexts in the classroom or training situation.

fig 6.4 Situated Learning. Source: https://www.thoughtco.com/thmb/jEZZ9wAYFw4clSO8e0xg-SOZfIdA=/2576x2576/smart/filters:no_upscale()/children-on-a-school-field-trip-in-nature-528905069-5c1d9beec9e77c00010b4c9b.jpg-captivating-class-room.png

For Example, the Australian company named FLAIM Systems develops Immersive learning situations which would be too hazardous to recreate in real life. (Forbes, April 19 2021) FLAIM Extinguisher© immerses trainees in of a range of fire events to efficiently train first responders.

Embodied Cognition

Embodied Cognition is a theory of Cognitive Science. This approach emphasizes that cognition typically involves acting and sensing with a physical body (Not just the brain) in the immersed environment (Schneegans, Schoner, 2008)
For example, hearing the word water can trigger a mental state associated with experiences of water (e.g., what it looks like, how it moves, feels, etc.
IR Technology is able to to achieve psychological immersion by combining aspects of Actional, Symbolic, Sensory and Social immersion. ((Liu, Dede, Huang & Richards, 2017)).*"Immersive reality technology is able to create powerful and meanigful experiences by generating visual, auditory, and tactile senses." (Li, Huang, Tian, Wand, Dai, (2019)*. Due to these affordances, IR allows the occurence of Situated learning and Embodied Cognition in learning scenarios.

fig 6.5 Embodied Cognition. Source: (van Dijk, 2014)

Transfer

Transfer in learning is when knowledge gained in one context can be used in another. (Perkins & Salomon, 1992) For example, mathematics and statistics learnt in the classroom can help in daily finances.
According to Dede (2017) *"a problem of teaching methods today is the low transfer created by traditional curriculum." (Liu, Dede, Huang & Richards, 2017)*

fig 6.6 Transfer. Source: https://elearningindustry.com/wp-content/uploads/2017/03/how-to-improve-learning-transfer-and-retention.png

"Learning in properly created digital scenarios can lead to proper replication in real world applications." (Fraser et al., 2012; Mayer, Dale, Fraccastoro, & Moss, 2011; Norman, Dore, & Grierson, 2012) Situated learning is important in part because of transfer.

Constructivism

Piaget's Theory of Constructivism (1935) is one of the most important pedagogical theories in educational VR (Duffy & Jonassen, 2013). Constructivism (is very similar to Situated Learning (Dede, 2017) It is based on the idea that people actively construct or make their own knowledge, and it is determined experiences as a learner.

Complimenting Constructivism is Constructionism. Constructionism, Papert's theory, involves *"experiential learning where students engage in exploration, create things that are personally meaningful, and share them with others." (Griffin, 2019)*

"In these activities, students are able to create immersive environments, or are told to create something within one." (Liu, Dede, Huang & Richards, 2017) For example, Kerbal Space Program is a game designed to let children build rockets and launch them to different planets and moons. Building the rockets helps students understand concepts of weights, thrust and aerodynamics, and launching them can help them understand acceleration, velocity and gravity.

IR Learning uses these theories to enhance learning as it allows student to construct their own knowledge from meaningful experiences. *"It allows one to construct visual and manipulable objects to represent knowledge, an allowance that traditional learning methods lack." (Hu-Au, 2017)* They are also able to share such objects and experiences with their peers or teachers.

fig 6.7 Constructivist Activity in the classroom. Source: http://photos.demandstudios.com/getty/article/251/146/78482364.jpg

fig 6.8. Constructivism. Source: https://www.instructionalcoaches.com/wp-content/uploads/2021/05/000.png

Gamification

Gamification of education can be a powerful tool when dealing with difficulties regarding lack of motivation or engagement in students.

Education already uses a point based system. You earn these point by completing tasks and receive grades to level up. However educational environments fail to capture the engaging and motivational aspects of games. (Lee, Hammer, 2011) *"Through gamification, students understand the importance of practicing and developing attributes like creativity, and perseverance"(McGonigal, 2011)*

AR/VR technology has already made long strides in the gaming industry. So it feels like common sense that the technology can help education by bringing in an element of gamification. However we must remember that gamification is just a technology, and while applying is, we must carefully understand it's overlap with the pedagogy discussed above and the content.

Gamification again stems from the Theory of Constructivism.

One must keep in mind however that playfulness requires freedom - *"the freedom to experiment, to fail, to explore, and to control one's own experience" (Klopfer, Osterweil & Salen, 2009)* One needs to be careful to not make gamification "feel" like the classroom, it is important to preserve the motivational and engaging qualities of games for it to be useful.

Educational Games such as Radix and World of Warcraft School can thus have a great impact when combines with the Technologies and Pedagogies of Immersive Learning.

fig 6.9 Gamification of Education. Source: https://i0.wp.com/www.niallmcnulty.com/wp-content/uploads/2016/07/gamification.png?fit=1423%2C924&ssl=1

Case Studies

Veative

Veative is a company based in Noida, Uttar Pradesh who works on providing IR solutions for Education and Enterprises in India. They have a large library of interactive and educational content in various subjects including STEM, History & Culture, Language Learning, and even in higher education subjects such as Engineering, Medicine etc. They have worked with various client around the world. They have their VR headsets which cost from-

The veative library consists of over 500 modules in subjects ranging from STEM, history, language and even engineering and medicine. Each module consists of a immersive directed narrative. The following infographics displays the different modules and their details.

Veative's mission is to Immerse, Interact and Inspire. It believes that AR & VR can increase focus and concentration, and help a student connect with a concept. *"It can traditions and cultures to life and allow for a connection with art, history and architecture to strengthen, and empathetic bonds to manifest."* (Sushma Sharma, Veative) According to them VR is able to promotote Higher order thinking skills.

fig 7.1 Veative module- Pedagogical Agents

Ms. Sushma in an interview conducted by us also stated that *"Unlike a video or a teacher-centred lesson, the control is in the hands of each student, allowing them to control the pace."* Teachers are a part of the experience through reports and analytics and thus the idea of learner agency and independence while making teacher-time more efficient and valuable.

Even though AR is useful for a younger target audience, Veative believes it can be distracting in higher standards. Similarly, not everything benefits from gamification. A cookie cutter approach doesn't work.

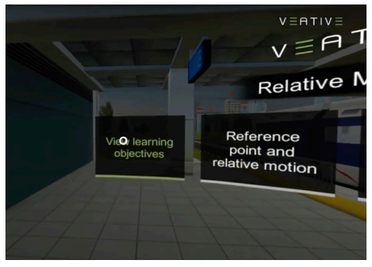


fig 7.2 Veative module- Directed Narrative

fig 7.3 Veative module- Directed Narrative

fig 7.4 Veative module- Virtual Tour

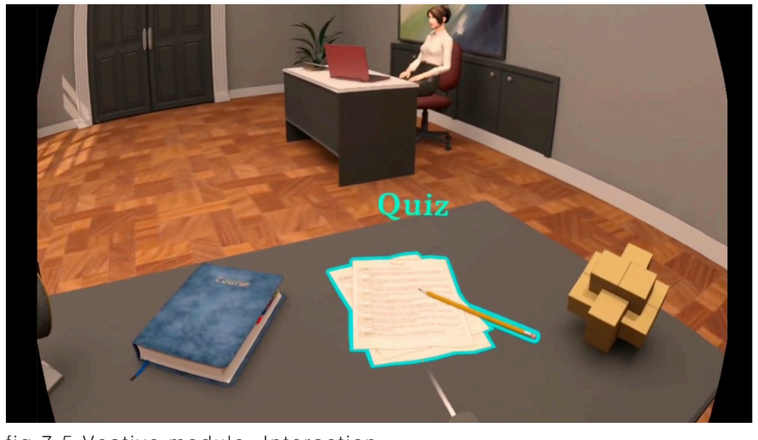


fig 7.5 Veative module- Interaction

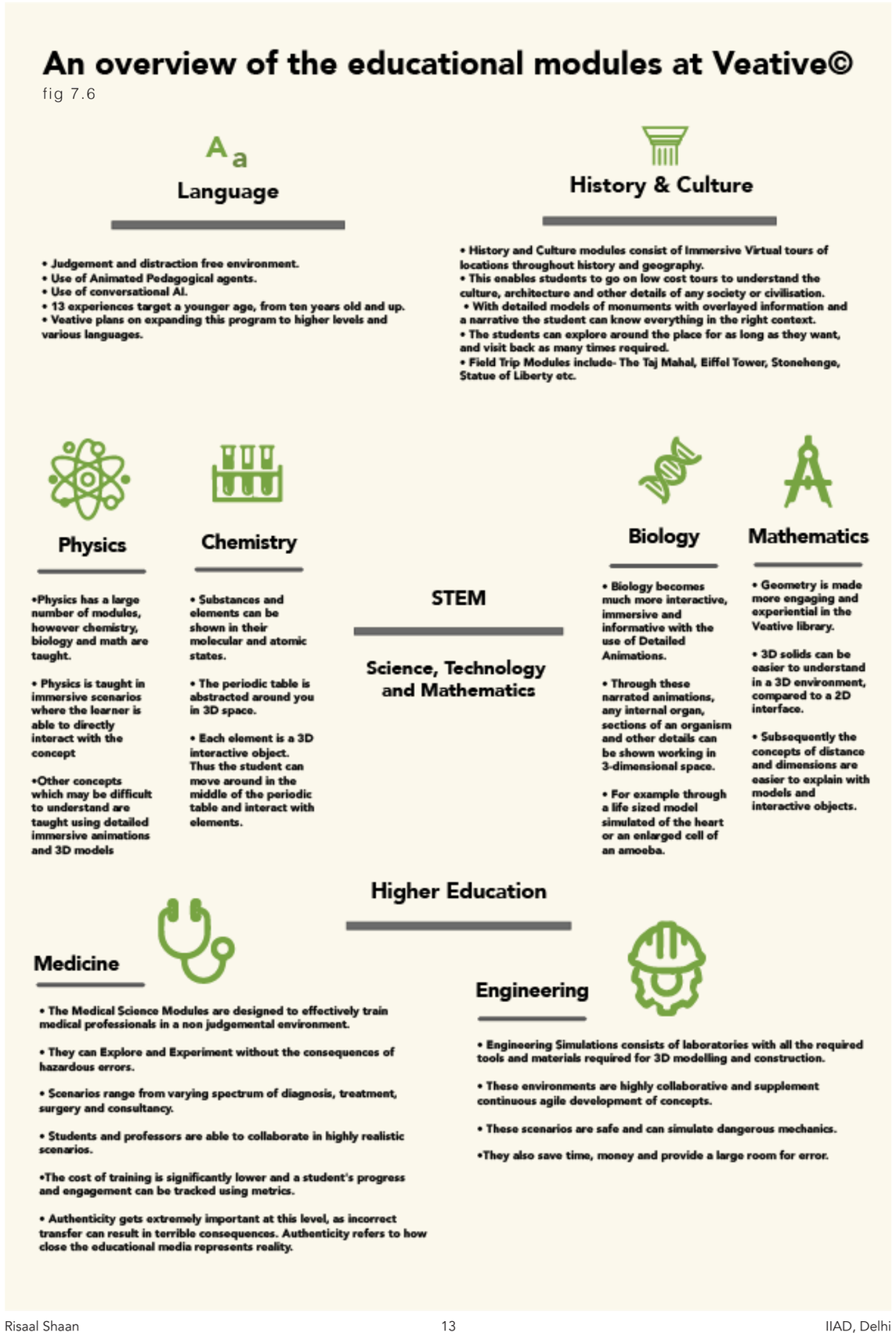


fig 7.6

Catchy Words AR

Catchy words AR is an elementary level Language Learning Application for mobile devices. The app uses 3D models of letters scattered across the room. A child has to walk around the room to pick up and organise the letters to form words.

Jaime Donally in the brilliant book (2021) discusses how the app has had a profound impact on her own daughter in her struggle to learn Words. Jaime speaks about her daughter Elli, who due to dysexia was not able to recall spelling of words. Catchy words AR has really changed this process. She says, "*If our brain has to work this hard for success, it's smart enough to know to hold on to that information for the future, so it doesn't have to work that hard again."* Elli was able to remember spellings of words only after going through the activity once.

We can see here a quintiscential example of situated learning, embodied condition, transfer and gamification.

By creating a spatial experience and involving the entire body, the mind is able to recall the mental model of the subject.

fig 7.7 Catchy Words AR App.
Source: https://miro.medium.com/

EcoMUVE

EcoMUVE, is a desktop application that was developed by the Harvard Graduate School of Education. It is a Multi User Virtual Environment used to teach middle school students about ecosystems and causal patterns. EcoMUVE was released in 2012, and it was not a VR application. However we can learn a lot about their approach to virtual environments for education.
The EcoMUVE Pond is a feature in ecomuve where one can find various immersive scenarios and context where one is able to learn science concepts, scientific inquiry, and complex causality. For example, if all the fish in the fond die, then students need to study the air, soil and other aspects to determine causality. Students can find answers to their queries by exploring and collecting information from around the ecosystem. (Dede, 2017) It allows students to view any ecosystem in any point in history, with any weather; in teams or individually.
Even though EcoMUVE is a desktop application, however Dede (2017) states using MUVE's can be useful while designing VR educational content, especially to create Immersive Environments with rich contexts.

fig 7.8 EcoMUVE.
Source: https://www.researchgate.net/profile/M-Tutwiler/publication/259729040/figure/fig1/AS:484995354632192@1492643311029

GridlockED

"Games let learners solve complex problems with a large amount of freedom to explore their own narrative." (Dede, 2017)
Gridlocked is a game developed by Tsoy et al. as a serious educational game, for students, to acquire the skills on how to treat a patient in a collaborative manner. It was created to enable future doctors learn how deal with patients in a safe environment, with enough freedom for exploration and room for error.
In GridlockED, one works collaboritively to efficiently manage all patients without being overburdened. The rules are simple, you need to take care of as many patients as possible, survive your shift and gain maximum points. Points are rewarded as per difficulty of the patient's treatment.
Even though GridLockED was originally a board game, it shows promise in terms of simulating a virtual immersive context in which the students operate. Such games can be used in a useful manner when augmented with immersive technology. (Tsoy, 2019)

fig 7.9 GridlockED.
Source: https://www.hamilton-healthsciences.ca/wp-content/uploads/2019/06/GridlockED-board-game-Teresa-Chan-web-size-15.jpg

Technology-Pedagogy-Content Overlap in Case Studies

In our case studies, we have seen uses of the ideas of pedagogy we discussed before. Each module in veative is carefully created by technology experts, teachers and educationalists. Here we already see the overlap of technology and pedagogy. This overlap is even more evident when we look at their modules.
As we mentioned before, Physics and STEM have a high level of overlap with VR technology and the pedagogy we discussed in the earlier sections. Concepts and physical properties can thus be considered optimum for the overlap of IR. Similarly, virtual fields trips are a powerful tool to learn history and culture due to the embodied cognition associated with learning at the very place an event occurs.
We have also noticed as the level increases, the level of authenticity also becomes very important. Even though authenticity is always important, it is important to realise that the degree of importance must increase as does the level of education.
In catchy words AR we see effective use of gamification and constructivism; along with embodied cognition to provide a tactile and sensory approach to learning spelling.
In EcoMUVE we see how complex and detailed immersive environments can be created to explore complex scenarios that encourage freedom of exploration and learning. And in GridlockED we saw how collaboration and learning can happen in realistic learning scenarios to foster transfer.
We see pedagogies play out in various degrees in the examples discussed earlier. We have also seen various ways of designing content shown in fig 8.1.

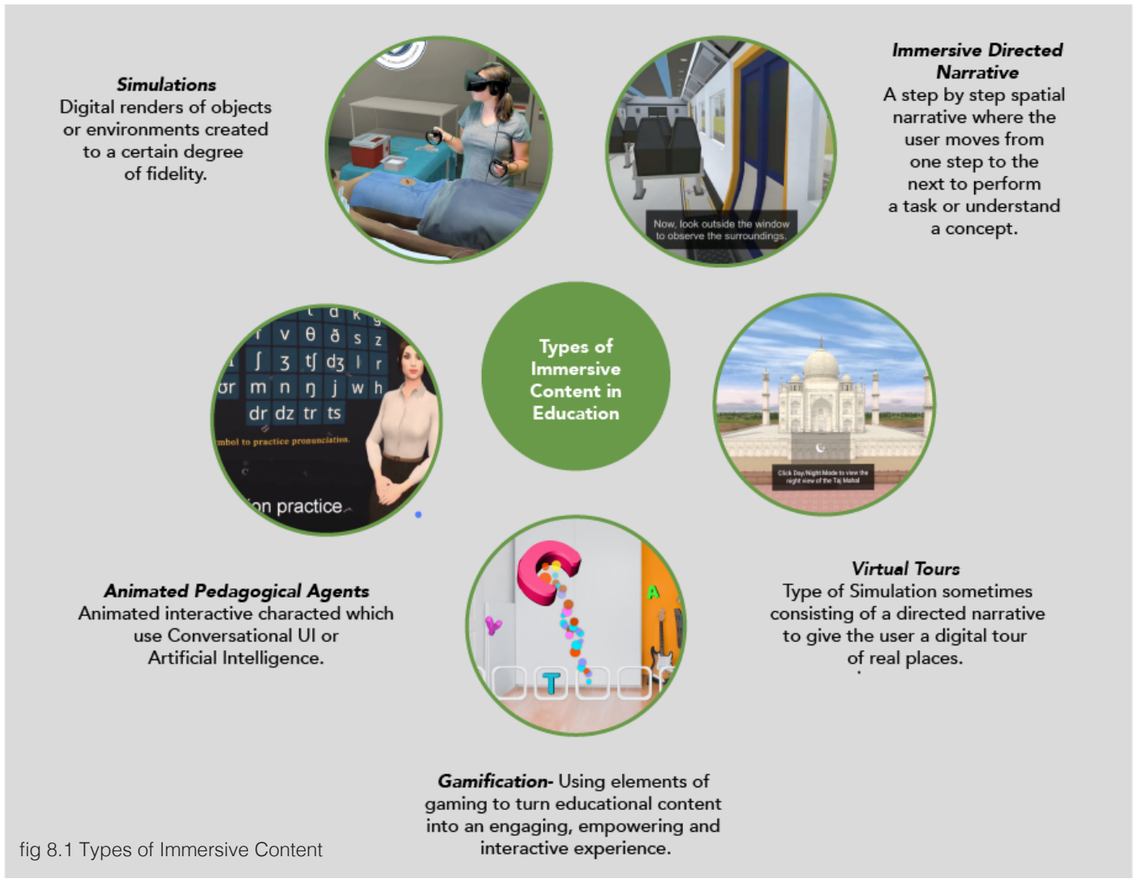


fig 8.1 Types of Immersive Content

Creation of Mental Models through Spatial Arrangement of Information

In the last section, we established that a cookie-cutter approach wouldn't work for educational content design. However, In this section, we propose a manner in which the AR/VR content design process can be simplified for any educational material by the extraction of mental models into the spatial dimension.

Mental models are organized systems (often visual) consisting of concepts and information, that helps a student relate to concepts and solve problems. (ENNS, 2021) *"Empirical evidence has been used in identifying a significant correlation between spatial ability and educational performance particularly in science, technology, engineering and mathematics (STEM)" (Buckley, Seery & Canty, 2018)*

We use mental models to understand everything around us. Studies have shown relations between mental models and spatial ability. The spatial ability helps us understand structure and relationships. *"Understanding spatial relationships is both fundamental and crucial for the creation of mental models." (Chatterjee, 2011)* Spatial abilities are one of the most studied factors of human cognitive functioning (Carroll 1993). *"Spatial ability has become increasingly related with a student's performance in STEM." (Höffler 2010; Lubinski 2010; McGrew and Evans 2004; Wai et al. 2009)*

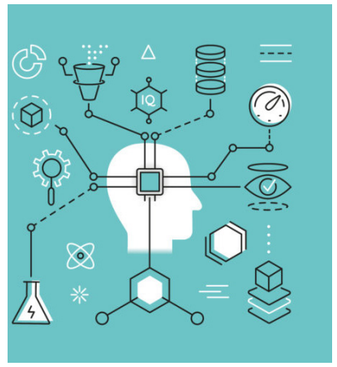


fig 8.1 Mental Models.
Source: https://www.litmos.com/wp-content/uploads/2017/12/Mental-Models_Litmos-500x500.jpg

We thus propose:

Education can be considered as the formation of mental models in a student. Hence, theoretically anything in the curriculum can be a mental model. This mental model usually transfers from the Teacher to the student. However, if we are able to **abstract this mental model into the spatial dimensions**, then we may be able to use Immersive technology effectively. In such a spatial model-

1. Concepts and ideas are shown as physical objects that can be interacted with. One's own space can contain physical objects determining knowledge they have acquired, such as a globe to show geographic knowledge, to which one can go to review or expand their knowledge.

2. Related artefacts and concepts are closely spaced and a distant concept is physically distant.

3. Tasks can be in the form of physical obstacles to be overcome.

4. The pursuit of the subject can be created through actual paths where one travels to uncover knowledge in a systematic manner.

Let us consider the following example:

Suppose the standard model of particle physics is to be taught to a student in twelfth grade in a CBSE curriculum. The teacher has a mental model of the standard model in his mind. The model (fig 8.2) would consist of: fermions, bosons and quarks, their mass, spin and other properties. He now has to transfer the same to a student in a systematic manner. (Example of this mental model can look this-

Now let us imagine a room in which the student can enter. It is a circular room with four curved tables on opposite sides (as shown in fig 8.3). There is a circular table in the centre of the room. On side table one, there are three round glowing balls, these are the up quark and the related quarks. You touch the ball and it glows, when you pick it up, you transport it to a minuscule scale and see them inside an atom. Similarly, you see the down quark on the next table.

Next imagine the items on the third table are locked, except for an experiment with the instructions, on performing which, you can discover the electron. Similarly, the child can perform actual experiments to unlock neutrinos and other leptons etc.

Once a child can grasp the concepts, they can move on the further outside of this to any scenario, for example, to a tesla coil to further understand electron movement, or to the sun to understand solar neutrinos.

The concept of extracting mental models into spatial models stems directly from the ideas of situated learning, embodied cognition, constructivism and other theories we discussed earlier. The concept can be applied to any discipline. A place where students use objects instead of numbers to calculate. A place where you can travel at the speed and scale of light and see its properties. A personal mind palace of all your knowledge. We are only limited by our imagination!

We can also see how our case studies like Catchy words AR and Veative have done this to a certain degree!

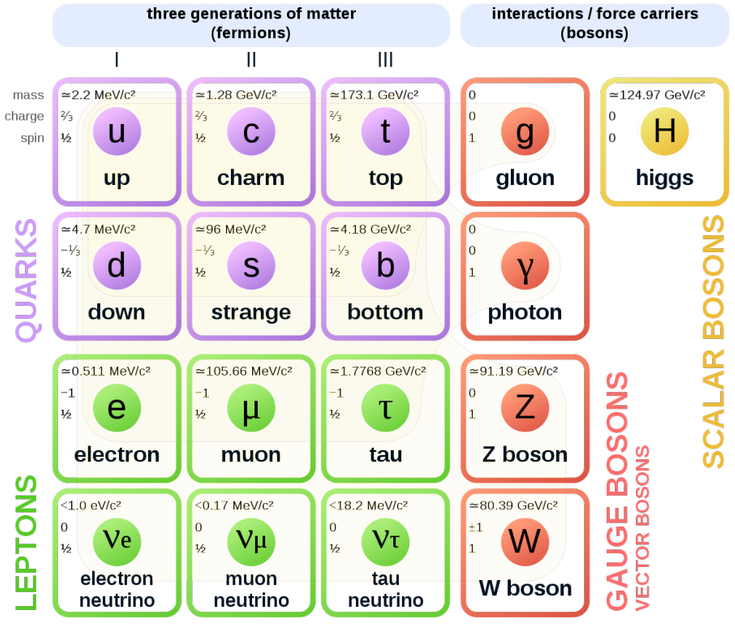


fig 8.2 Standard Model of Particle Physics- A visual representation of the metal model.

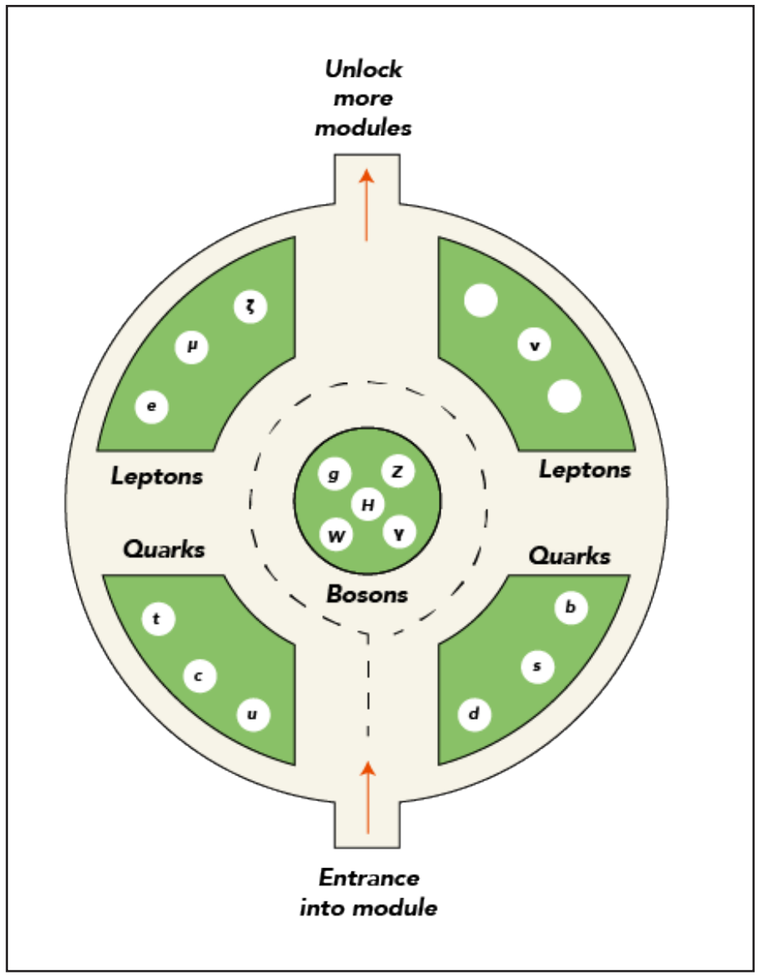


fig 8.3 Spatial Arrangement of the Standard Model

Conclusion

In this paper, we have discussed various ways in which the technology of Immersive Reality overlaps with Education and Pedagogy. We see this overlap is evident with various pedagogical and cognitive theories like situated learning, embodied cognition, constructivism and more play an interesting role. However, immersive content has not been able to fully maximise this technology so far. This is due to the lack of a framework, in which educational content may be turned into immersive content.

In our discussions we have realised a cookie-cutter approach doesn't work since all disciplines have specific needs which need to be considered before designing content for the same. However, we have also realised that there may be a way to maximise the potential of immersive learning- by abstracting mental models into the spatial environment.

By this approach we may be able to use immersive learning the way it was intended, to provide meaningful, powerful and engaging immersive experiences, so the students can truly relate to a concept.

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