The Integration of Emerging Technologies in Architecture, Construction and Engineering Higher Education Pedagogy.

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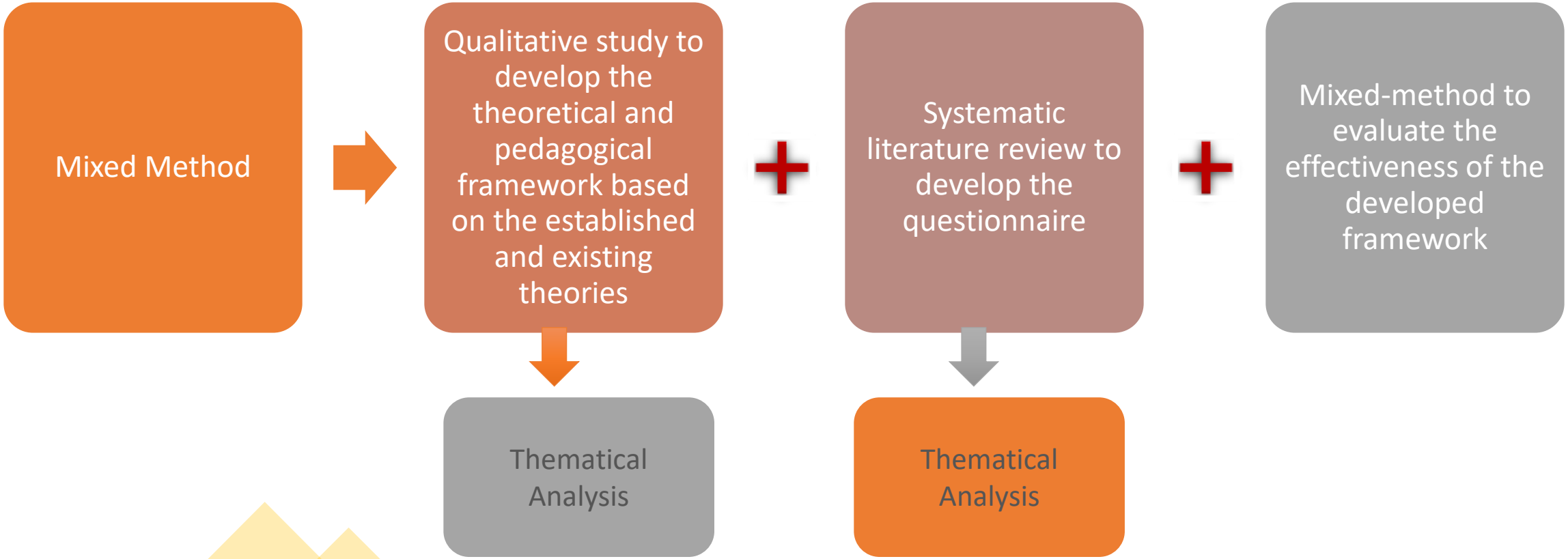
Over the past decade, the architecture industry has been evolving from traditional practices into more current, interdisciplinary and technology-integrated methods.

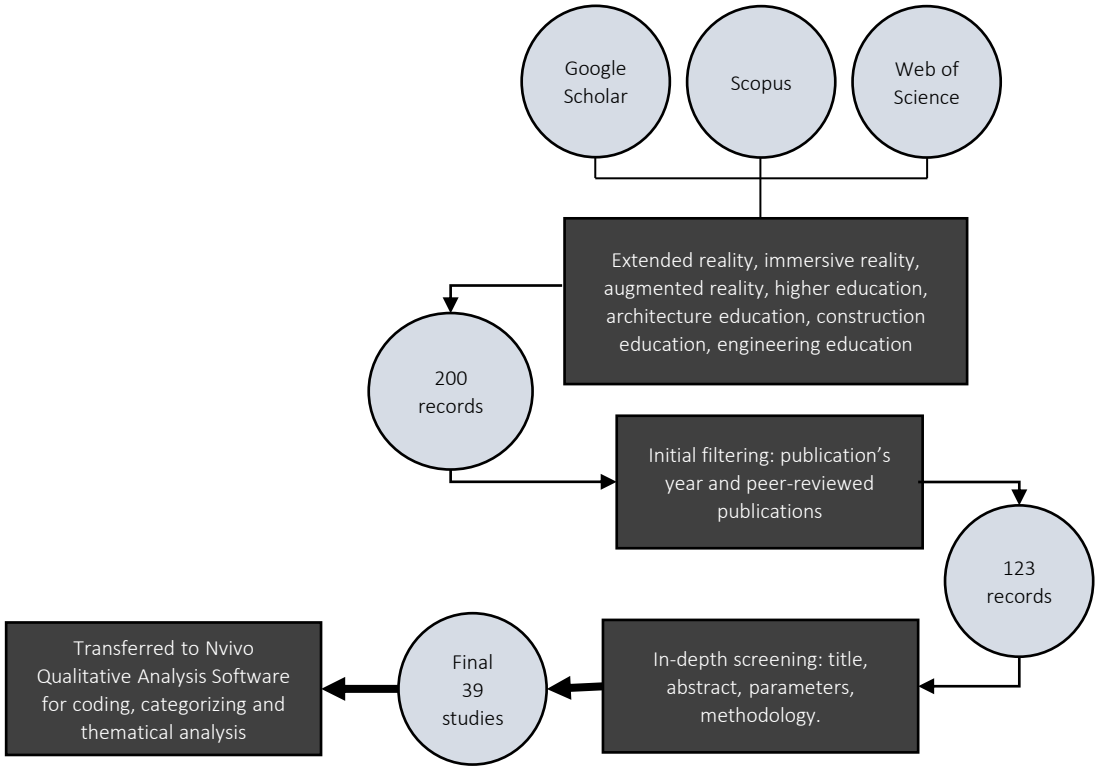
- **Complex and intricate digital technologies and mobile computing such as simulation, computational design and immersive technologies, have been exploited for different purposes such as**
  - **reducing cost and time**
  - **improving design**
  - **and enhancing overall project efficiency and sustainability**

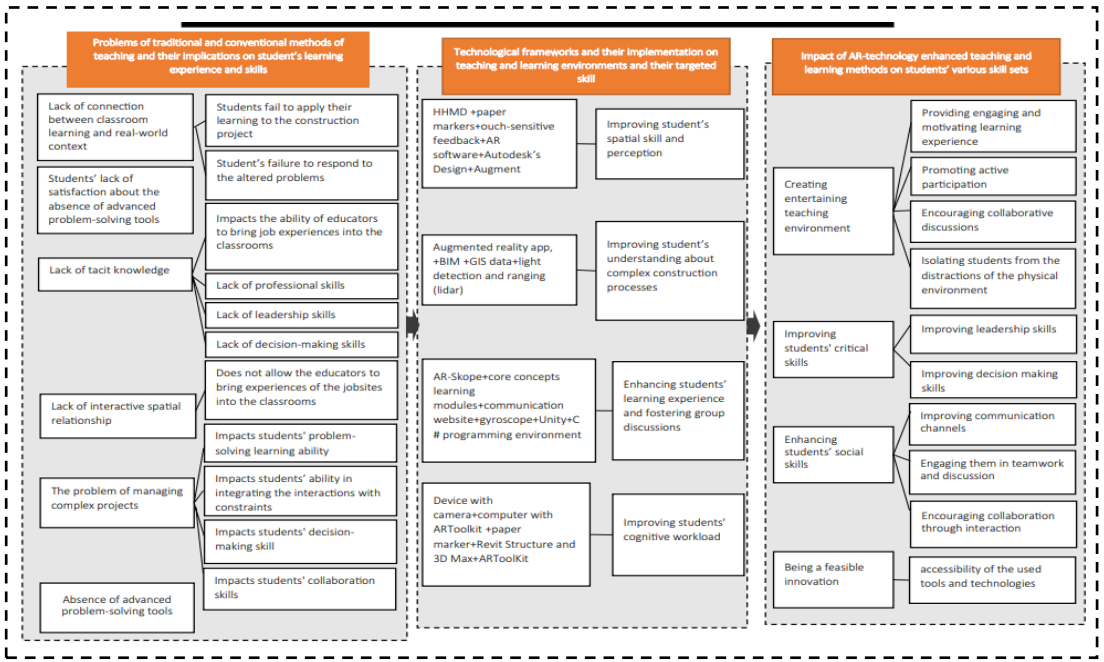
GAP

- However, the application and usage of these technologies and devices in higher education teaching and learning environments **are yet to be fully explored and are still scarce**. More importantly, there is still **a significant gap in developing pedagogies and teaching methods that embrace the usage of such technologies in the AC curricula**.


Mixed Method
Qualitative study to develop the theoretical and pedagogical framework based on the established and existing theories
Thematical Analysis
Systematic literature review to develop the questionnaire
Thematical Analysis
Mixed-method to evaluate the effectiveness of the developed framework

- A qualitative method was utilised to develop the applied pedagogical framework, and a quantitative approach was utilised to collect and analyse data.




Problems of traditional and conventional methods of teaching and their implications on student's learning experience and skills
Lack of connection between classroom learning and real-world context
Students fail to apply their learning to the construction project
Students' lack of satisfaction about the absence of advanced problem-solving tools
Student's failure to respond to the altered problems
Impacts the ability of educators to bring job experiences into the classrooms
Lack of tacit knowledge
Lack of professional skills
Lack of leadership skills
Lack of decision-making skills
Does not allow the educators to bring experiences of the jobsites into the classrooms
Lack of interactive spatial relationship
Impacts students' problem-solving learning ability
Impacts students' ability in integrating the interactions with constraints
The problem of managing complex projects
Impacts students' decision-making skill
Impacts students' collaboration skills
Absence of advanced problem-solving tools
Technological frameworks and their implementation on teaching and learning environments and their targeted skill
HHMD +paper markers+ouch-sensitive feedback+AR software+Autodesk's Design+Augment
Improving student's spatial skill and perception
Augmented reality app, +BIM +GIS data+light detection and ranging (lidar)
Improving student's understanding about complex construction processes
AR-Skope+core concepts learning modules+communication website+gyroscope+Unity+C # programming environment
Enhancing students' learning experience and fostering group discussions
Device with camera+computer with ARToolkit +paper marker+Revit Structure and 3D Max+ARToolKit
Improving students' cognitive workload
Impact of AR-technology enhanced teaching and learning methods on students' various skill sets
Creating entertaining teaching environment
Providing engaging and motivating learning experience
Promoting active participation
Encouraging collaborative discussions
Isolating students from the distractions of the physical environment
Improving students' critical skills
Improving leadership skills
Improving decision making skills
Enhancing students' social skills
Improving communication channels
Engaging them in teamwork and discussion
Encouraging collaboration through interaction
Being a feasible innovation
accessibility of the used tools and technologies

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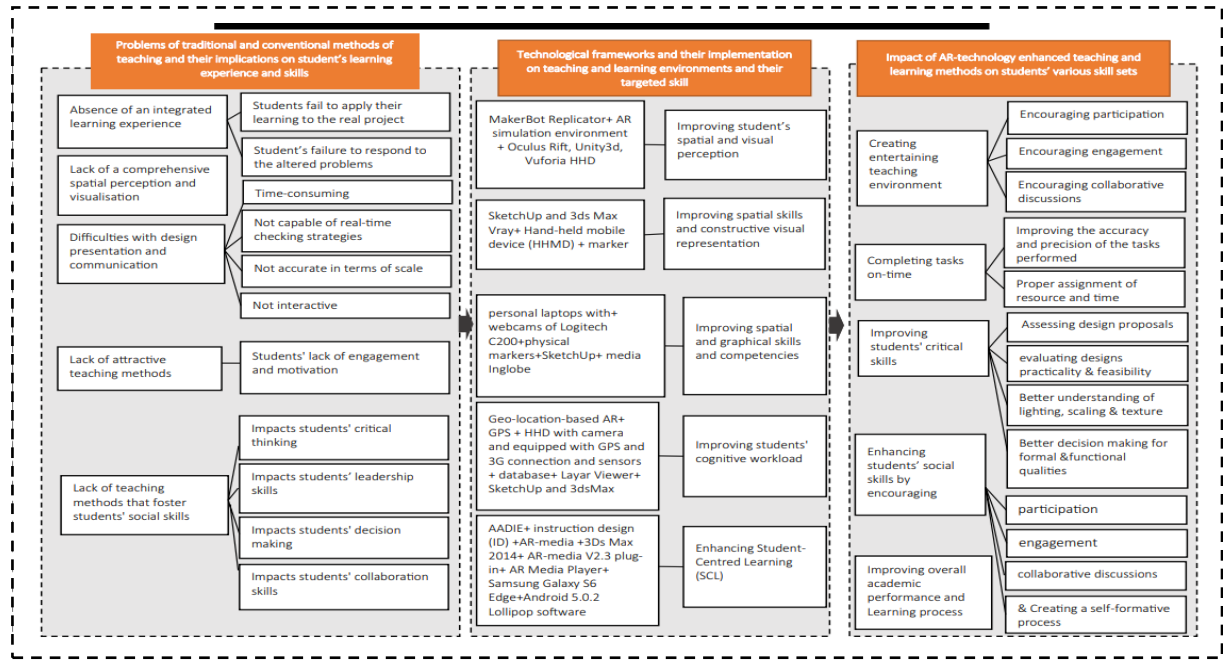
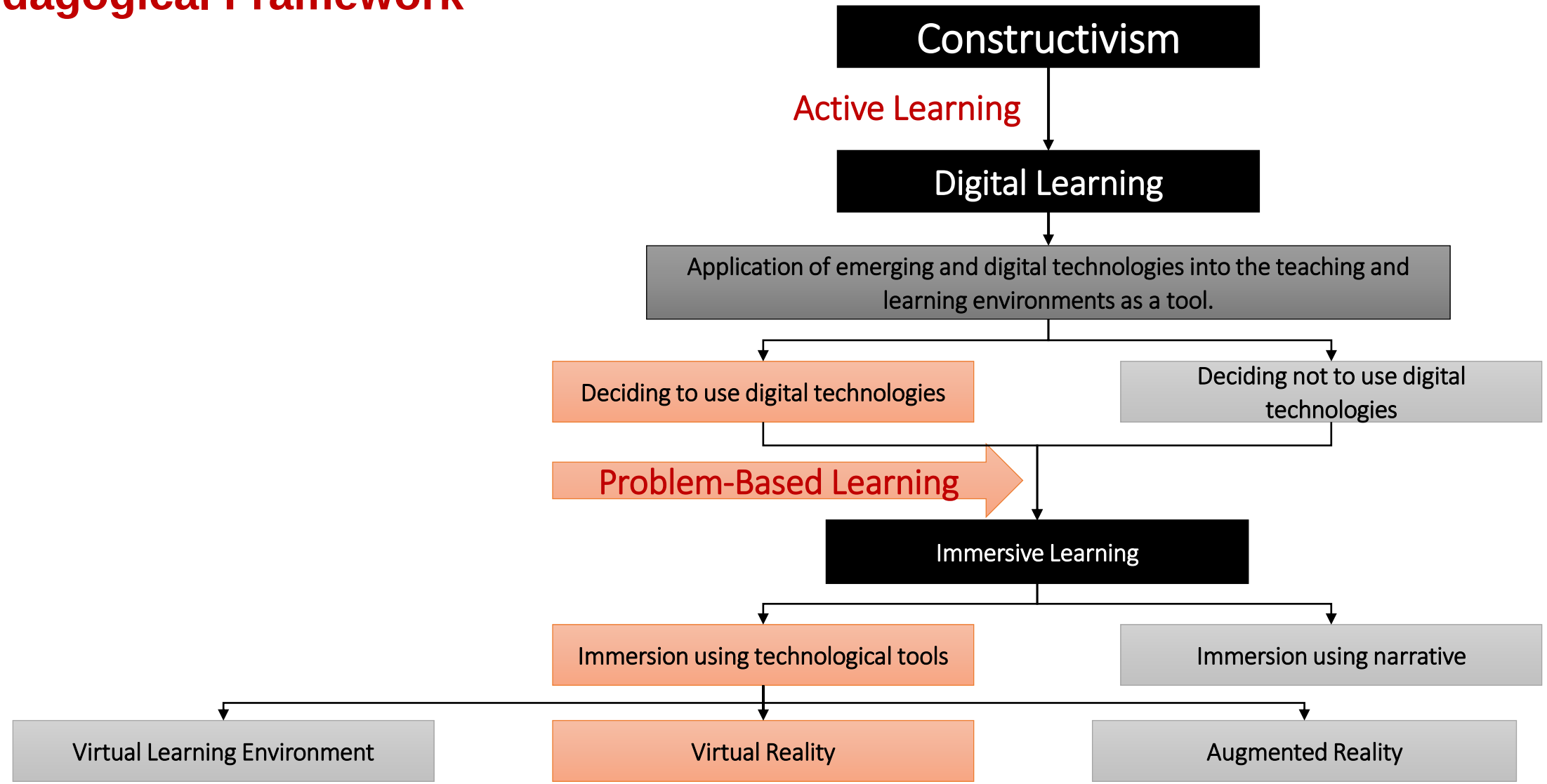

Problems of traditional and conventional methods of teaching and their implications on student's learning experience and skills
Absence of an integrated learning experience
Students fail to apply their learning to the real project
Student's failure to respond to the altered problems
Lack of a comprehensive spatial perception and visualisation
Time-consuming
Difficulties with design presentation and communication
Not capable of real-time checking strategies
Not accurate in terms of scale
Not interactive
Lack of attractive teaching methods
Students' lack of engagement and motivation
Impacts students' critical thinking
Lack of teaching methods that foster students' social skills
Impacts students' leadership skills
Impacts students' decision making
Impacts students' collaboration skills
Technological frameworks and their implementation on teaching and learning environments and their targeted skill
MakerBot Replicator+ AR simulation environment + Oculus Rift, Unity3d, Vuforia HHD
Improving student's spatial and visual perception
SketchUp and 3ds Max Vray+ Hand-held mobile device (HHMD) + marker
Improving spatial skills and constructive visual representation
personal laptops with+ webcams of Logitech C200+physical markers+SketchUp+ media Inglobe
Improving spatial and graphical skills and competencies
Geo-location-based AR+ GPS + HHD with camera and equipped with GPS and 3G connection and sensors + database+ Layar Viewer+ SketchUp and 3dsMax
Improving students' cognitive workload
AADIE+ instruction design (ID) +AR-media +3Ds Max 2014+ AR-media V2.3 plug-in+ AR Media Player+ Samsung Galaxy S6 Edge+Android 5.0.2 Lollipop software
Enhancing Student-Centred Learning (SCL)
Impact of AR-technology enhanced teaching and learning methods on students' various skill sets
Creating entertaining teaching environment
Encouraging participation
Encouraging engagement
Encouraging collaborative discussions
Completing tasks on-time
Improving the accuracy and precision of the tasks performed
Proper assignment of resource and time
Improving students' critical skills
Assessing design proposals
evaluating designs practicality & feasibility
Better understanding of lighting, scaling & texture
Enhancing students' social skills by encouraging
Better decision making for formal &functional qualities
participation
engagement
collaborative discussions
& Creating a self-formative process
Improving overall academic performance and Learning process

1. Creating more effective and entertaining teaching and learning environment
• Providing engaging and motivating teaching and learning experience • Promoting active students' participation • Encouraging collaborative discussions • Benefits students by isolating them from the distractions of the physical environment
2. Enabling students to complete task efficiently and in a timely manner
• Improving the accuracy and precision of the tasks performed • Enabling students to properly assign resources and the expenditure of time and effort for solving the proposed exercise
3. Improving students' critical skills
• Providing students, a tool to assess their design proposals • Providing students, a tool to evaluate their designs practicality and feasibility prior to any intervention • Enhancing the overall understanding of the built forms by diminishing the problems and issues of lighting, scaling, and texturing • Fostering the process of decision making for formal and functional qualities

4. Enhancing students' social skills
• Encouraging participation • Encouraging engagement • Creating a self-formative process • Encouraging collaborative discussions
5. Improving students' spatial competencies
• Improving students spatial and visual perception • Improving spatial skills and constructive visual representation • Improving spatial and graphical skills and competencies • Improving spatial skills, developing critical judgement and self-evaluation skills

Pedagogical Framework



Advanced Design Communication is a first-year Master of Architecture subject, which was redeveloped as a requirement of the university-wide research project of NPILF (National Priorities and Industry Linkage Fund), to create a more **industry-oriented and research-led teaching** approach at higher education.

Based on the industry partners' insights and research evidence, **digital and immersive technologies were used not only to enhance visualisation and student engagement** but also to teach students about social justice and sustainability, inclusivity and architectural professional practices.

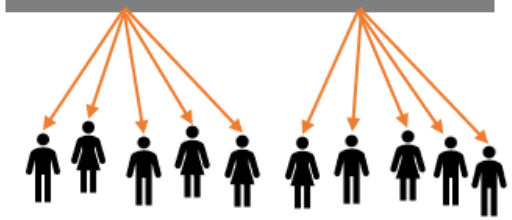
1

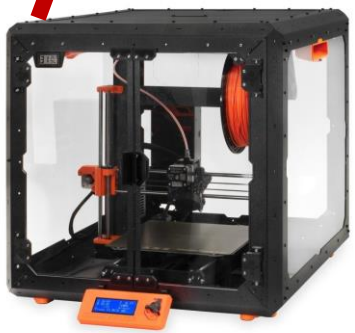
Study the site, pick a point in history that appeals to you or provokes you

Develop your individual manifesto that represents you as an emerging architect

Create an abstract drawing

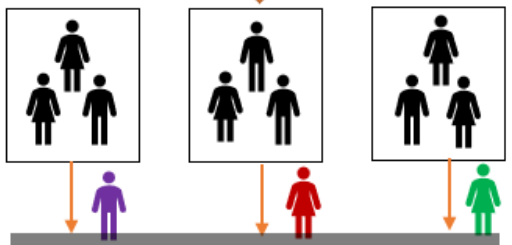
Now turn it into a 3D printed sculpture





2

Form groups & pick a client



Understand your clients dilemmas, need & requirements; role play as a professional architectural team; re-write your manifesto to reflect on your team and your client

Create an abstract drawing

Now turn it into a 3D printed sculpture

3

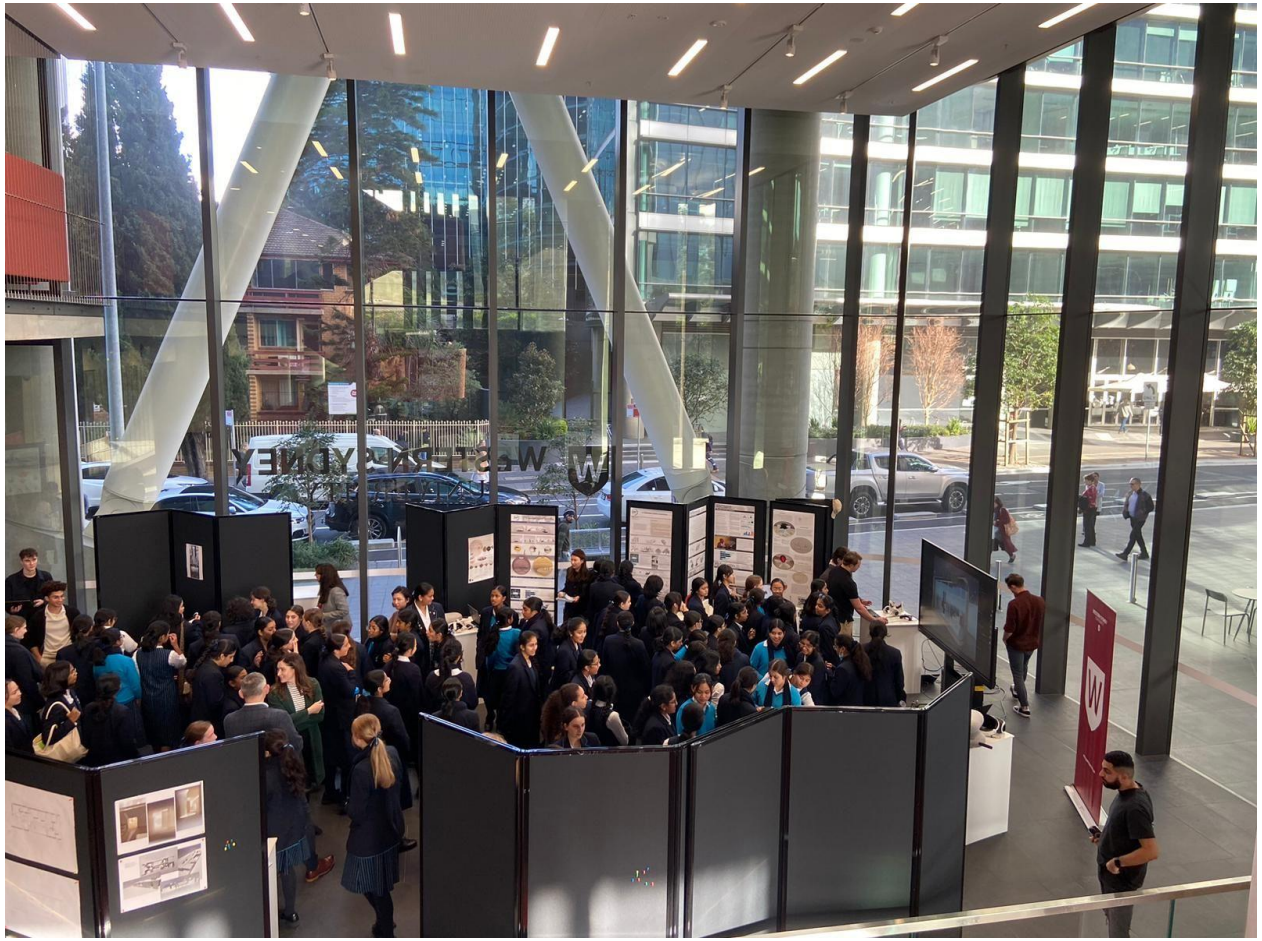
Provide a solution to the identified clients problem by developing an architectural intervention (it can be as small as 3x3x3

3D laser scan the site as a team

Augment your architectural intervention into the scanned site using virtual reality technology


& THE NAKED

We hosted 100 Our Lady of Mercy high school students to showcase our new subject's results, sparking inspiration for their future endeavours. The success led their senior staff to request further collaboration and engagement with WSU.



Results

1. **Real-World Experience:** Students gain hands-on experience with **industry-standard technology, enhancing their readiness for professional practice**.
2. **Spatial Understanding:** such technologies provide an in-depth understanding of **spatial relationships and proportions**, essential for architectural design.
3. **Collaboration:** Facilitates interdisciplinary collaboration with engineering and construction students, mirroring real-world projects.

Results

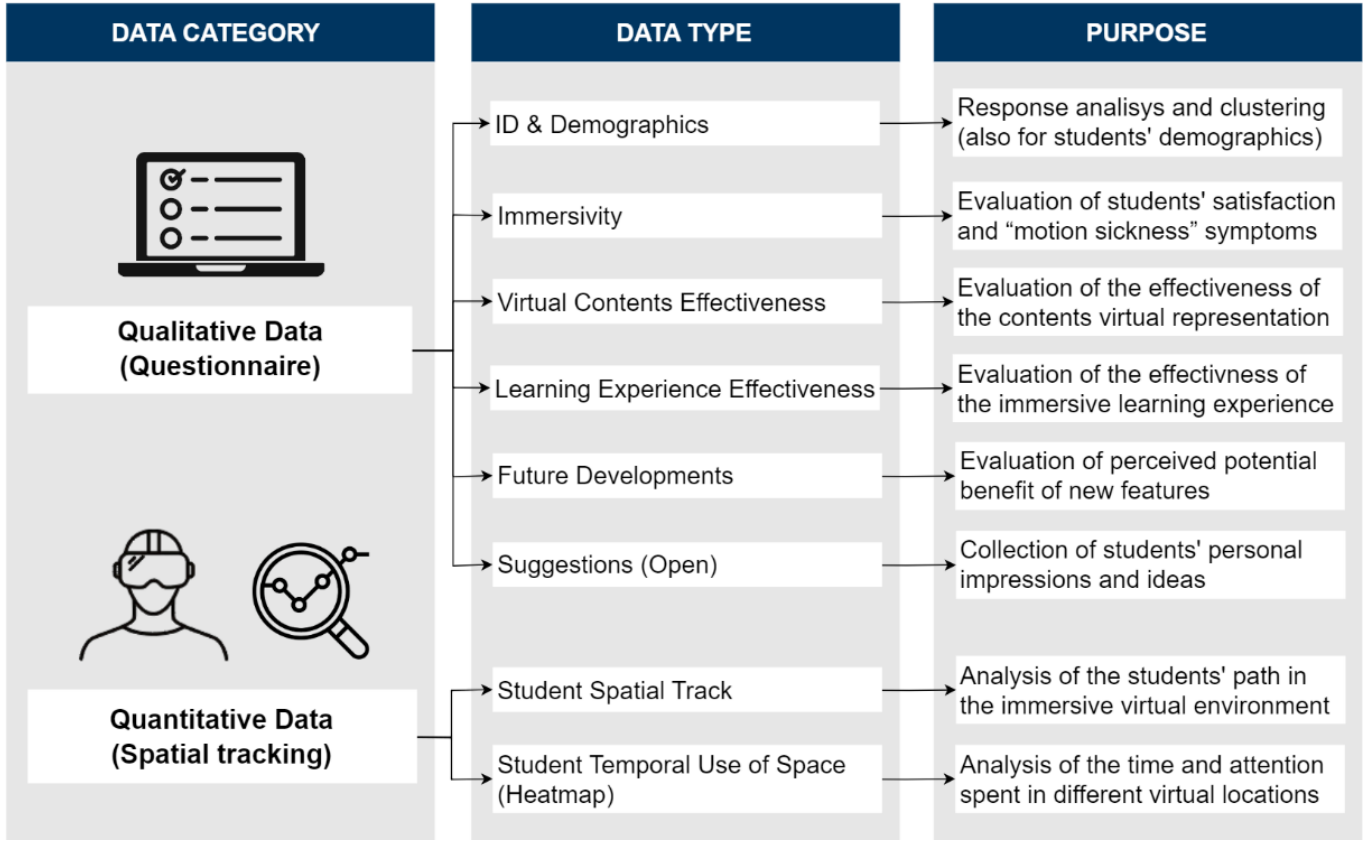
4. Visualization: 3D models enhance communication of design ideas to peers and instructors.

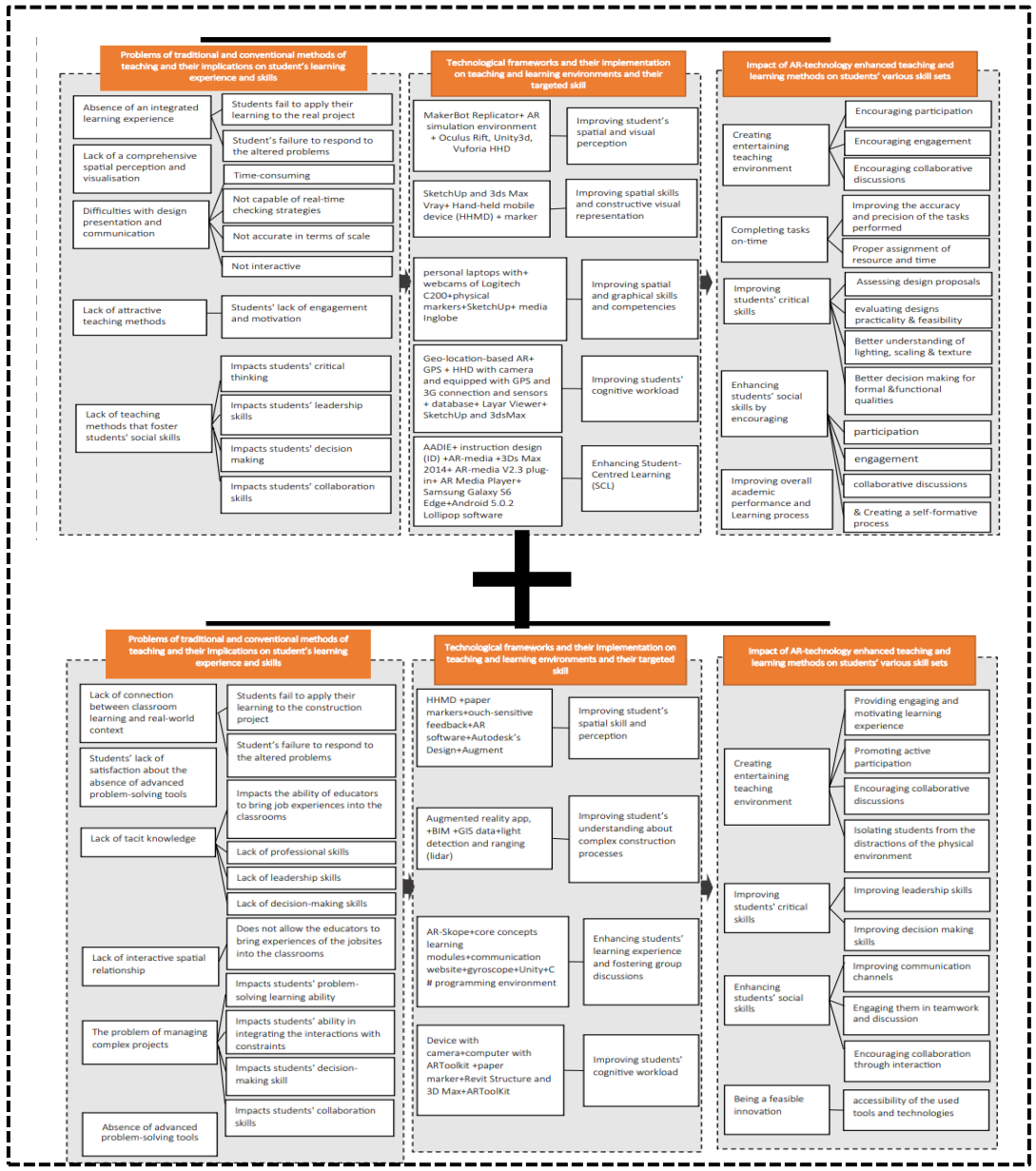
5. Career Readiness: Graduates with digital skills appear to be more attractive to employers in the architecture and construction industry.

6. Innovation: Sparks innovative thinking as students explore the possibilities of cutting-edge technology.

Evaluation Mixed-Methods

- An original method for the evaluation of immersive VR learning experiences was developed, considering both **qualitative subjective data and quantitative objective observations**





Data type	Description	Example
ID & demographics	Data necessary to analyse and classify the responses collected through the questionnaires with reference to the occurred immersive learning experiences, and to cluster their results also with reference to the students' demographics (anonymized). [Various]	Questionnaire ID: (Text) Immersive experience: (Text) Date: (yyyy/mm/dd) Age: (Number) Gender: (Multiple options) Course: (Text)
Immersivity	Questions related to the student's ability to get immersed in the virtual experience. They are useful for assessing how engaged the students were in the virtual world and to evaluate their satisfaction in terms of both ease of use and comfort (also related to the possible onset of symptoms of "motion sickness"). [Single rating – Likert scale]	How much did you like the experience? [min 1; max 5]
Contents effectiveness	Questions regarding the virtual representation of the learning contents, aimed at evaluating the effectiveness of the experience against the objectives of the session. [Single rating – Likert scale]	How efficiently and clearly does the content of VR help you to perceive the discussed subject better? [min 1; max 5]
Learning experience effectiveness	Questions pertaining to the overall effectiveness of the experience, aimed at investigating the actual usefulness of the immersive VR learning session compared to traditional methods, especially concerning the learning objectives. [Single rating – Likert scale]	Do you think this experience is useful in understanding the qualities of the designed spaces? [min 1; max 5]
Future developments	Questions concerning the introduction of new features (e.g., content animations, audio and visual effects, etc.) or virtual content aimed at enhancing the immersive VR learning experience through the inclusion of greater realism and/or interactivity. [Single rating – Likert scale]	Would you like to be able to grasp and interact with objects in the VR environment? [min 1; max 5]
Suggestions	Open questions to collect personal impressions and ideas from the students. [Text box]	Suggestions

Evaluation Method- Quantitative (Questionnaire)

Data type	Description	Example
ID & demographics	Data necessary to analyse and classify the responses collected through the questionnaires with reference to the occurred immersive learning experiences, and to cluster their results also with reference to the students' demographics (anonymized). [Various]	Questionnaire ID: (Text) Immersive experience: (Text) Date: (yyyy/mm/dd) Age: (Number) Gender: (Multiple options) Course: (Text)
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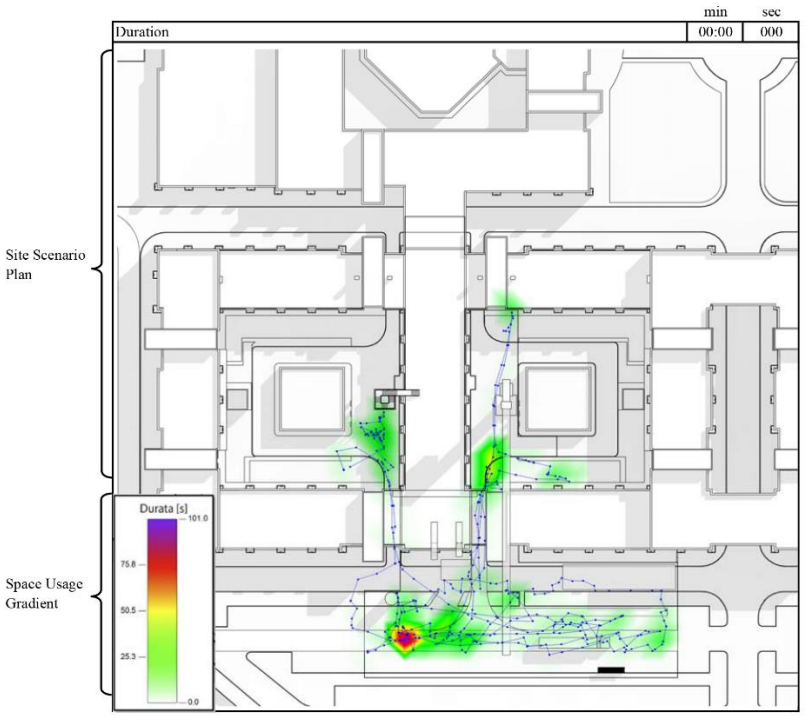
Suggestions	Open questions to collect personal impressions and ideas from the students. [Text box]	Suggestions

Evaluation Method- Qualitative



Student spatial track heatmap representation – Implementation prototype

Data type	Description	Example
ID & demographics	See Table 1.	See Table 1.
Learning experience duration	The duration of the experience from start to finish, excluding a possible tutorial or time required to the student to get used with the immersive VR system and controllers. This is necessary to allow for the later heatmap visualization of the student use of the virtual space weighted on the overall elapsed time. [time in seconds]	Duration: (number) sec
Student spatio-temporal track	The student position in the virtual environment is collected as 3D point with 1 Hz frequency. The corresponding spatial track is then graphically represented against a model of the experienced environment (e.g., BIM model) both as a 3D path (polyline) and with an heatmap representation, with the colour gradient weighted on the time spent in a certain location.	Colour gradient representation of the student's followed path (weighted by time) [min. green, max. purple]

Implementation & Validation

Institution	Course (Academic Year 2023/2024)	Expected attendees
Western Sydney University, Australia	• Advanced Design Communication (ARCH7007)	50
	• ARCH7015 Practice Research Studio Civic (ARCH7015)	50
University of Florence, Italy	• BIM and Information Modeling of the Construction Process (B028836)	50
	• Design and Safety of Workplaces B030584 (B063)	50

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Thank you