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Article

The Experience of Learning in "The Cube": Queensland University of Technology's Giant Interactive Multimedia Environment

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Abstract: In this paper we report findings of the first phase of an investigation, which explored the experience of learning amongst high-level managers, project leaders and visitors in Queensland University of Technology's (QUT) "Cube". "The Cube" is a giant, interactive, multi-media display; an award-winning configuration that hosts several interactive projects. The research team worked with three groups of participants to understand the relationship between: (a) the learning experiences that were intended in the establishment phase; (b) the learning experiences that were enacted through the design and implementation of specific projects; and (c) the lived experiences of learning of visitors interacting with the system. We adopted phenomenography as a research approach, to understand variation in people's understandings and lived experiences of learning in this environment. The project was conducted within the first twelve months of The Cube being open to visitors.

Keywords: QUT; The Cube; giant interactive displays; multimedia walls; experience; learning; phenomenography

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1. Introduction

What makes a giant, complex and interactive multimedia environment any more than a 10 metre tall touch screen? What makes it achieve any more than a mesmerizing Las Vegas-style mass of glittering lights? We are presently able to construct such complex systems and have begun to introduce them into higher education institutions; however, we have limited insight into learning experiences in such environments. The question of what makes learning possible is related not only to the technology and its capabilities, but also to the way humans interact with and experience learning in such environments. This paper presents the first phase of an investigation into the experience of learning, from the perspective of various stakeholders in The Cube environment. Figure 1 portrays parts of The Cube space.

Figure 1. QUT's Cube [1].

The Cube, at Queensland University of Technology (QUT), Australia, was created to "showcase QUT's teaching and research within STEM (Science Technology Engineering and Mathematics) disciplines" [2] (p. 1). Its four 8.5 m by 4.5 m walls attract a wide range of visitors, including school children, members of the general public, researchers, tourists and university students. An important purpose of The Cube is to create opportunities for learning, whether these visitors (up to 70,000 per week) come with an intention of learning or not. Other purposes of The Cube include introducing the community to cutting edge science and technology, and marketing the university's capabilities [3].

At the time this study was conducted, during the first twelve months of the existence of The Cube, five applications were being displayed:

- The Virtual Reef: An education-oriented simulation of the Great Barrier Reef that enables users to manipulate, explore and interact with the reef.
- The Community Science Wall (Flood wall): An application that allows the public to connect with Queensland stories and experiences, told through an interactive map and timeline.
- ECOS (a Green building simulation): A game-like application, which uses interactive data and illustrations to help people understand how everyday energy use impacts people in a "green" building.
- The Physics Playroom: A simulation for exploring physical principles in an environment where the gravity governing the space can be modified.
- CubIT: A multi-user presentation, interaction and collaboration platform, which allows QUT's users to display their content (video, image and text) via The Cube's infrastructure [2].

The first three applications allowed single user interactions, which could blend into a group experience, the fourth allowed multi-user interaction, and the fifth allowed multi user interactions, incorporating the possibility of distributed experiences.

The early visions of The Cube saw it as "a public education program, (with) visualisation research capacity, modeling and simulation, physical construction of the walls, and a collection of launch applications" [2] (p. 3). A key challenge in designing The Cube was to implement an infrastructure that simultaneously supported "applications suitable for general public" and "significant ongoing research and education programs" [2] (p. 2).

Contributions to learning have been an important element of The Cube's design from the beginning. For example, the Virtual Reef was created to reveal the basic functionality of an ecosystem and display marine life behaviour, as well as provide pop-up information that aligns with school curricula. Also, ECOS is a game style application, which helps people learn how decisions they make concerning climate control, such as temperature and humidity, can impact on energy consumption and generation.

We now report findings of empirical research into people's experience of learning in The Cube from three different perspectives of high-level managers, designers and developers, and visitors.

Together, the results capture the experience of learning in The Cube, producing a portrait of that experience in the early stages of its existence. This includes what learning is planned (high-level managers' experiences), what is done to enable learning to happen (project leaders' experience) and how that learning is experienced (visitors' experience). While some aspects of these experiences are aligned with each other across different groups, there are gaps observable in some aspects. While high-level managers maintain a broad perspective of visitors learning about QUT expertise, project leaders' perspectives are limited to the purposes and outcomes of their specific project for users. Although sometimes different from what visitors experience, there are occasions project leaders' intentions are aligned with visitors' lived experiences. Moreover, the results indicate that high-level managers have a more expansive vision in terms of learning strategies compared to the practical vision of project leaders, with which visitors' experiences of learning strategies is mostly aligned.

2. Literature Review

Large interactive displays have been the focus of technical research for the last ten years, with the earliest work occurring around 2000 [4]. Since that time, the main emphasis has been on research associated with the technical aspects of display walls, including architecture, design application and systems.

Very little research into people's *experiences* of such environments has been conducted to date. Duarte *et al.* [5] (p. 1) acknowledged this gap, and began to address it by exploring "how users interact with the display and each other during collaborative tasks" (p. 1). The importance of this stems from the need, identified by Chen *et al.* [6], to solve the problem of how to make successful collaboration possible using large multi-touch displays in public spaces. However, Lasso, the environment used in Duarte's study, was only 3 m wide by 1.2 m high. Additionally, Huang *et al.* [7] explored the challenges involved in adopting such systems for group work in workplaces.

One small scale study conducted by a group of university students investigating user experience of The Cube produced the observation that "some focused more on the object while others focused more

on the context, and this gave us an idea on how we could focus more on the parts that we might naturally neglect. By comparing the differences between how each of us experienced The Cube we got inspired to focus on areas that we usually might not consider" [8].

No literature has been found to date on people's learning experiences in such environments, which asks questions like, "What is being learned?" and "How is that learning occurring?" Questions about what learning is planned or experienced have not yet been raised. Nevertheless, the potential for influence on learning is recognized and is one of the key goals of projects in The Cube environment [2].

While phenomenography has been used extensively to explore learning in coursework contexts, including scientific and technical concepts [9], and also learning in virtual environments [10], it has yet to be tested for its potential to uncover learning experiences in cutting edge technological spaces such as The Cube.

3. Research Aims and Questions

Our study investigated the experience of learning in The Cube from the perspective of key stakeholders. The research questions addressed were:

- What kind of learning was planned for The Cube (by high-level managers)—the Intended Cube;
- What was planned and done to enable learning to happen in The Cube (by designers and developers)—the Enacted Cube; and
- What experiences of learning result from engaging with The Cube (by visitors)—the Experienced Cube.

The findings associated with these three questions are compared to give insight into the relationship between the experiences.

4. Methodology

4.1. Participants and Context

The research thus explored the perspectives of three groups who are key players associated with learning in The Cube:

1. Cube high-level managers who determined overall policy (3 people).
2. Cube project leaders who developed specific projects (4 people).
3. Cube visitors who interacted with the developed projects (12 people).

Participants in the first two groups were interviewed individually. In the third group, participants engaged with the team as either individuals or in small groups. When talking with individuals in the third group, sometimes the person being interviewed turned to a companion or companions, in some cases children, accompanying them. Most of The Cube visitors could best be described as "sightseers", rather than them coming with specific learning intentions in mind.

4.2. Method

The phenomenographic approach to research, originally devised to explore critical elements of people's awareness or understanding of objects of study, has the investigation of variation in experiences as its key research object [10,11]. Recent phenomenographic directions have interpreted learning scenarios [12] as incorporating three aspects: a teacher's intended lesson, the enacted lesson, and the learners' experienced lesson [13]. Some studies, which have explored lessons from these points of view, include Marton and Pang [14], Rovio-Johansson [15], Runesson [16], and Maybee *et al.* [12].

In this study we adapted these ideas to investigate learning experiences in The Cube. In translating the ideas from researching classroom learning to The Cube, we recognise that we were not dealing with: (a) a traditional face to face learning situation; (b) the learning of a small suite of ideas normally associated with a single lesson; and (c) a single teacher, nor a relatively homogenous group of students. Instead, a range of people established intentions associated with The Cube, including high-level managers and project leaders. The Cube itself did not involve a single lesson, but rather multiple projects representing different fields; and the visitors varied in age, gender and background. The process of translating researching "classroom lessons" to The Cube environment led us to conceptualise three key areas of focus:

1. The Intended Cube: High-level managers' plans for The Cube and its learning experiences were obtained through extended conversations with key individuals who lead the development and implementation of the facility as a whole. This focuses on the *vision* for The Cube.
2. The Enacted Cube: Project leaders' considerations of learning experiences in The Cube, especially in relation to the projects they were developing, were obtained through extended conversations with key individuals leading the development and implementation of specific projects. This focuses on Cube *implementation*. Project leaders were seen as enacting, or realising, the vision of high-level managers. This enactment included both intentions and constructions.
3. The Experienced Cube: Visitors' learning experiences were sought through observation and short interviews (5–10 minutes with individuals or groups). This focuses on *interaction* with The Cube.

4.3. Data Collection

Data gathering processes included observation and interviews. Observations were conducted in addition to short interviews to interpret visitors' experiences. Interviews were conducted as the primary way of interpreting high-level managers' and project leaders' experiences.

4.3.1. Observation

Observations of Cube visitors occurred over a period of several hours, including weekdays and weekends. Observers maintained sufficient distance to be relatively inconspicuous. Observers dressed in the style of the general public, wore a QUT staff identity card, and used a notebook to record detailed notes of relevant activity within The Cube e.g., touching the walls, reading the content, interacting with others in the space. Observations focused on:

- What spaces are being used?
- How are these spaces being used, and what is occurring there?
- What appears to be informing visitors?
- What learning appears to be occurring?

4.3.2. Interviews

Semi-structured interviews were conducted with all three participant groups. The primary questions asked appear in Table 1.

Other questions were asked, to encourage elaboration of points made, for example, "Can you tell me more about…?" The focus was on creating a natural, free flowing conversation with the participant.

Phenomenographic interview questions are intended to orient the participants towards the phenomenon of interest (in this case the experience of learning in The Cube), to enable concrete descriptions as well as abstract responses, and to be sufficiently open to allow respondents to respond from their own point of view.

Questions, which conform to these principles, are most likely to allow variation in experience to be explored.

Table 1. Interview questions asked of the three stakeholders groups.

High-level Managers: The Intended Cube	**Project Leaders: The Enacted Cube**	**Visitors: The Experienced Cube**
Please describe your role in The Cube environment.	What was/is your role, concerning the Cube?	Why are you visiting The Cube?
When planning The Cube, what did you want people to learn?	What did/do you put into place to help people learn in The Cube?	Have you learned anything today in this place?
When planning, what did you consider to be the key learning goals of The Cube environment?	What did/do you expect people to learn in The Cube?	What have you learned?
When planning The Cube, how did you expect people to learn?	How did/do you expect people to learn in The Cube?	How did you learn it?

4.4. Data Analysis

In accordance with the phenomenographic research approach, data for each group of participants was explored in order to discern, from the participants' perspective:

1. What was learned (the learning object).
2. How learning happened or was intended to happen (the learning strategy).
3. How the learning opportunities were constructed.

Thus, for the high-level managers we were able to identify their intended learning objects and learning strategies. For project leaders, we were able to identify their intended learning objects and learning strategies, as well as the manner in which they went about constructing learning possibilities.

For the visitors we were able to identify their experienced learning objects and experienced learning strategies.

For each group of participants we were also able to discern different ways of experiencing The Cube itself. This has been identified as a dimension of variation, meaning that it is an aspect of the experience of learning in The Cube that is important for all groups; between the groups, however, the experience of The Cube varies.

The purpose of phenomenographic analysis is to discern variation in the experienced meaning of the phenomenon being explored, in this case the experience of learning in The Cube. Different ways of experiencing the learning object, learning strategy and The Cube itself were evident amongst all groups of participants.

Table 2 shows the various parts of the analysis and how they relate to the interview questions. Detail of what was found is elaborated in the next section. A complete table (Table 3) showing the parts of the analysis, the interview questions and the key elements of the findings appears at the end of the data analysis section.

Table 2. The experience of learning in The Cube: Relating the conceptual tools of analysis to the interview questions.

	High-level Managers "Intended Cube"	**Project Leaders "Enacted Cube"**	**Visitors "Experienced Cube"**
Ways of experiencing the object learning	Intended learning objects When planning The Cube, what did you want people to learn?	Intended learning objects What did/do you expect people to learn in The Cube?	Actual learning objects Have you learned anything today in this place? What have you learned?
Ways of experiencing learning strategies	Intended learning strategies When planning The Cube, how did you expect people to learn? When planning, what did you consider to be the key learning goals of The Cube environment?	Intended learning strategies How did/do you expect people to learn in The Cube?	Actual learning strategies Have you learned anything today in this place? How did you learn it?
Ways of experiencing the development of learning	N/A	Enacted development What did/do you put into place to help people learn in The Cube?	N/A
Ways of experiencing The Cube	From responses to all questions	From responses to all questions	From responses to all questions

5. Findings

The findings from this exploration of people's experiences of learning in The Cube are presented in three parts:

- The first set of findings describe the Intended Cube. They convey the kind of learning that was planned for The Cube by high-level managers.
- The second set of findings describe the Enacted Cube. They convey what was planned and done to enable learning to happen by project leaders, The Cube's designers and developers.
- The third set of findings describe the Experienced Cube: They convey the actual experiences of learning resulting from visitors' engagement with The Cube.

Illustrative quotes provide examples of the experiences described. Each quote is followed by the interview number and a HM, PL or V code, which stand for High-level Mangers, Project Leaders or Visitors, respectively.

5.1. High-Level Managers' Intended Cube

High-level managers' intended Cube is described in terms of their intended learning objects, intended learning strategies and own experience of The Cube.

5.1.1. High-Level Managers' Intended Learning Objects

High-level managers of The Cube indicated they expected The Cube visitor would learn about QUT expertise, STEM or "anything". As was mentioned above, these were the intended learning objects in The Cube.

Learning about QUT expertise involves visitors learning about experts who are researching and participating at QUT:

> *I, particularly myself wanted people to learn that there was an incredibly skilled group of people within the QUT community who had capacity that was yet to be fully crystallised, realised, and learn about in this broad area of visualisation and simulation modelling. (int. 2-HM)*

Learning about STEM involves knowing that STEM is everywhere in a sense that STEM is present in every dimension of today's life, STEM is not scary and technology is valuable. Learning about STEM includes enhancing STEM (scientific) literacy:

> *STEM is not something that is over there in the lab with a guy in a white coat but actually STEM is completely our lives as they're entirely integrated from the two smart devices you've got on the table through to the technology to design and create my coffee cup through to my new blue bag, it's everywhere. And so that's really important I think as one of our missions is to show people how to re-frame this stuff from the old kind of seventies things to the new 21st century thing, which is everything. (int. 1-HM)*

> *the other desire was to raise essentially the scientific literacy of the community in general. (int. 2-HM)*

Learning about "anything" involves high-level managers' expectations of visitors' learning "something", which can be "anything" in a sense of random content. This "anything" can generate new insights for visitors, even if it is becoming aware that they do not know enough:

> *We're saying that a successful learning experience is that you came out of this richer, however that may be than you went into it, even if the thing that you learnt is that you clearly have absolutely no idea how electronics works and you that probably need to go to an easier course. It's fascinating. (int. 1-HM)*

5.1.2. High-Level Managers' Intended Learning Strategies

Cube high-level managers intended learning to happen in The Cube in three different ways, by: (a) users acting as scientists; (b) intervening at different levels; or (c) providing quality experiences.

Learning through acting as scientists may involve early involvement of mainly school students in STEM and conveying the idea that everyone is a scientist or engineer:

> *what we've already realised which is, if you want to get kids involved in STEM and the kids who don't think that they want to be scientists but we need them to be involved in STEM, you have to get them early enough and you have to introduce STEM in a way that doesn't appear like the Bunsen burner, physics teacher experience. (int. 1-HM)*

> *Another the next step on from that is everybody can be involved, everybody can learn, in fact everybody is a scientist, the technology is an engineer and a mathematician. (int. 1-HM)*

Learning through development of appropriate interventions involves three levels of intervention: no intervention, enabling self-directed engagement such as play, collaboration between visitors and independent discovery; limited intervention, enabling facilitated engagement such as using pedagogical materials or setting up workshops using semi-directed discovery; and strong intervention, enabling directed engagement where teachers deliberately teach content or processes:

> *It goes back to self-discovery, I expect them to discover whatever it is that they discovered or they learned. My job is not to go, "We are going to teach you X and that is what you will learn", my job is to go, "Here is an interesting thing, come and play, engage and discover for yourselves". (int. 1-HM)*

> *So you should accidentally learn something but you can also come with a coach load of kids and deliberately teach them something. So that's how I always expected people to learn. (int. 2-HM)*

Learning through providing quality experiences involves different views of quality as: A real-size synchronized view of complexity, a positive and engaging experience, a shared experience, or an experience delivered through use of clever tool sets:

> *The only presumption that I made was that if it was engaging enough and that people didn't have to read tones of stuff to be able to engage and that people got some kind of positive feedback experience, that … through engagement, which is physical sensorial visual game play they would learn something. (int. 1-HM)*

> *And the other tactic is in the how by using really smart powerful toolsets that are smart and simple, so we're being very strategic in the respect that we really championed Little Bits, Makey Makey, Arduino, Lego. We're just at the moment developing into conveyor*

> *conduct, so we're using very specific kinds of toolsets to facilitate those kind of environments. (int. 1-HM)*

5.1.3. High-Level Managers' Experiences of the Cube

As an aspect of the experience of learning in The Cube, high-level managers experience The Cube itself differently, as: (a) a technological artifact; (b) a learning facilitator; (c) showcase of expertise at QUT; or (d) a public management hub.

A Technological artefact may be in the form of sophisticated hardware or software:

> *So The Cube at QUT is several things. One of the things it is, is a sophisticated piece of hardware with some pretty sophisticated bits of software on it. (int. 1-HM)*

> *It's a demonstration of large scale advanced ICT in visualisation, simulation and interaction spaces. (int. 2-HM)*

A learning facilitator may be a facilitator of learning or a place of cumulative learning. As a facilitator of learning, The Cube is experienced as a learning environment or tool while as a place of cumulative learning, it is experienced as an environment where different minds can be brought together to solve 21st Century problems:

> *In its current predominate use, it's an educational facility. (int. 2-HM)*

> *It's an educational facility and it can educate people from many ages and many backgrounds, many styles and many types, which should, if it's continually refreshed, continue to do that for a long, long time. (int. 2-HM)*

A showcase of expertise at QUT demonstrates what QUT is capable of, in terms of the expertise of its human resources:

> *Again it was this point about showcasing the skill sets that were at QUT could only have been done by a fortuitous combination of people that happened to be here at the time with that skill set I think to be honest. (int. 2-HM)*

A public engagement hub is a unifier for public engagement and provides the stimulus and focus for different types of public engagement and programs to take place:

> *But The Cube is also a massive and actually a far bigger thing, which is it's a series of public engagement opportunities, workshops, talks, lectures, camps, classes, you name it. There's a whole bunch of other stuff, but The Cube is like the internal hub of a wheel and these are all the spokes that come off it. Without the object you couldn't actually have all of these spokes, they need the object to hold it all together, but the object itself is not the be all and end all. It's probably the heart of the whole program but it's not the program. (int. 1-HM)*

5.2. Project Leaders' Enacted Cube

Project leaders' enacted Cube is described in terms of their intended learning objects, their intended and enacted learning strategies, and their own experience of The Cube. As project leaders' intentions shaped their enactment, their intended learning objects and learning strategies are presented as integral to understanding their enacted learning strategies.

5.2.1. Project Leaders' Intended Learning Objects

Project leaders made learning experiences happen (*i.e.*, enact their intentions) in The Cube in three different ways. This included learning about (a) technology, (b) subject matter, (c) social interaction, and (d) learning itself.

Learning about technology includes learning to *interact with technology*, especially large touch screens; learning *what can be done with technology,* especially encountering a new experience of technology, leaving an impression of its uniqueness and complexity, scale and sophistication; and learning *what it takes technologically to do things.* This was meant to turn a WOW response to technology response into interest in discovering more and interest in subject matter relevant to implementing such technology, for example the underlying mathematics:

> *By coming into a public space like The Cube, [eighty year olds] are going to be exposed to a whole range of technologies that they usually wouldn't get exposed to at all. That's a really good educational outcome for them, that they come in, and because it's in this public space, they're almost forced to engage with this technology. Not in a bad way, but just because it's present, they're kind of forced to engage with it. (int. 2-PL)*

> *But what I was hoping would happen is that the technology would inspire them. That they'd kind of go "Wow, this is cool, I want to come and actually build some of this stuff!" And that they'd be a bit inquisitive and try and find out a bit more about how it happened. (int. 2-PL)*

Learning about subject matter includes learning *accurate information about things*; *new concepts*, introducing visitors to new ideas or unfamiliar concepts; and *subjects in school curricula:*

> *The reef turned into quite an elaborate exercise in what do we have to know, where does the information come from, is it valid? (int. 1-PL)*

> *The educational role was brought in as a requirement, but then there was this explicit requirement to respond to school groups and have curriculums. (int. 1-PL)*

Learning about social interaction includes learning how to work together while interacting in a shared space. It was anticipated that visitors, especially children, would need to learn the importance of social interaction in such spaces:

> *One of the interesting things about the physics playroom is that you've got a three year old jumping up and down, trying to move blocks around, and then their big brother,*

> *who's six, is also then coming along and throwing blocks on top of what the three year old is doing. The three year old is getting a collaborative experience out of that, so there's a social side that the three year old is probably getting out of it. (int. 2-PL)*

Learning about learning itself includes learning how to develop expertise through discovery and finding out how to make those discoveries; and learning *how to do high level research* through gaining insights into complex topics, and being impressed by how this level of research is conducted.

> *I wanted it to be more of a discovery thing... There was initially some thoughts that you would get some information or little pop ups about things. But there was like a mystery tour, like a location based game, but in that environment, and you had to go from one place to the other and some early ideas where you had to go along the whole thing to find out the story of things. (int. 1-PL)*

> *We should be looking at how can we use this physical space to build applications that are useful for chemists at the university, for doing cutting-edge research (int. 2-PL)*

5.2.2. Project Leaders' Intended Learning Strategies

Project leaders intended learning to happen in three different ways in The Cube through engagement with: (a) technology; (b) scientific content; or (c) different teaching/learning styles.

Learning through technology involves being inspired by technology to learn about technology:

> *One of the information panels in the physics playroom talks about the programming language that's been used to build it. ... So for obviously computer science and information technology students, I was hoping that they would actually kind of go: "Wow! This is cool that this wall has been built using not just software, but a programming language developed here at QUT!" Unfortunately that hasn't happened that much, but I was hoping that that's what would happen. ...What I was hoping would happen is that the technology would inspire them…and that they'd be a bit inquisitive and try and find out a bit more about how it happened. (int. 2-PL)*

Learning through scientific content involves the elaborate exercise of project leaders delivering accurate and scientific content:

> *And there [in Great Barrier Reef project] was the broad ecological story, which is the four zones that you see there, the dark stuff, the sand area and the near deep and the deep, and the various species there and why they would be there. So there was all these quite elaborate ideas. (int. 1-PL)*

Learning through different teaching/learning styles may range from adhering to national curriculum, to promoting discovery:

> *So I'm not sure when these things happened exactly, but there was a point where we said, "Look, we've got to coordinate with the notion of the national curriculum." (int. 1-PL)*

> *But getting back to the educational thing, yeah my idea was just to have it to be … a real science discovery thing. (int. 1-PL)*

5.2.3. Project Leaders' Enacted Learning Strategies

Project leaders make intended learning experiences happen in The Cube in three different ways. This includes testing technology; assuring the validity of the delivered content; and exploiting technological functions using simulation, and making interaction design simple and easy as well as using unique technical features:

> *The first six months of this year there was a fair bit of smoothing, nothing really changed to the eye, but it just was tied in and made a bit more reliable. … So there was a lot of systems stuff behind it. All of this effort was not directly related to the educational role, which a lot of people focused on. But we had to focus on just getting it to work reliably all the time. (int. 1-PL)*

> *We built interaction techniques that we thought were running through different very simple and very easy to use. We actually had a design process where we ran through several iterations of different interaction mechanisms. We looked at how people use them and how intuitive they were, how easy they were to activate (int. 3-PL).*

5.2.4. Project Leaders' Experiences of the Cube

As an aspect of the experience of learning in The Cube, project leaders experience The Cube as: (a) an educational site; and (b) a showcase for existing expertise within QUT.

An educational site involves seeing The Cube as *a science museum* (int. 1-PL, p. 5) and as a science show for the education of specific groups, such as high school students and chemists at QUT:

> *I think we have to stop thinking about The Cube as a way of implementing curriculum design for high school teachers. I mean, it shouldn't be about making an application to teach chemistry, for example. … I'm not saying we should be absolutely doing serious chemistry simulation experiences on The Cube, and they can translate to both the general public and high school students, but it shouldn't be specifically curriculum related. It should be far more general. We should be trying to solve problems for chemists at QUT, and as a by-product of that there will be things that we can put on The Cube. We should be looking at how can we use this physical space to build applications that are useful for chemists at the university, for doing cutting edge research? (int. 2-PL)*

A showcase of QUT expertise involves seeing The Cube as a showcase for showing off the technological capacity of QUT:

> *I was also quite interested really in just showing off the technology as well. … I don't think we should be ashamed of showing off the technology. It's okay to say to people can you please put this massive bit of technology into the space, and just say look at what cool stuff we can do with this technology. (int. 2-PL)*

5.3. Visitors' Experienced Cube

Visitors' experienced Cube is described in terms of their experienced learning objects, experienced learning strategies and own experience of The Cube.

5.3.1. Visitors' Experienced Learning Objects

Visitors learn about two qualitatively different things in The Cube: (a) technology; and (b) content.

Learning about technology includes learning about the type of technology used in the space, or how the technology works:

> *what I've learnt is actually about the way of displaying information and how interactive can be a good tool for passing on information to others who don't know. So, more so about the method of imparting information through this technology. (int. 9-V)*

> *A Cube visitor was treating the Community Science Wall like an iPad. The visitor was using his fingers to zoom in on the Google map like as he did when zooming in and out on an iPad. He did not have any success, so gave up and stepped back. However, after a while, he noticed the zooming buttons near the screen and decided to try again. He succeeded and continued his interaction (Obs. Sunday 22nd Sept)*

Learning about content often happens in interaction with textual content:

> *I was learning about the striped snapper, because I wasn't quite sure what they were.… What else? [wondering] I was learning about the different clams, the different fish and animals that I didn't know about before. So, yeah! Definitely [I learned something here]. (int. 2-V)*

5.3.2. Visitors' Experienced Learning Strategies

Visitors' learning about technology and content happens in three ways: (a) intuitive interactive features; (b) interpreting the technology; and (c) being in a social context.

Learning through intuitive interactive features involved using features in common with other applications, experimenting with how the technology works, and being stimulated to interact with the technology because it is easy:

> *And with the fish, there is the letter "I" to show you to touch there. (int. 3-V)*

> *By eventually working out which combination of touching and clicking and moving your fingers around got the right menus to come up, but that took a little while to work out. (int. 7-V)*

> *We found the original idea by accident, in that it was moving across the screen in front of you. So, you saw … Nemo! [You would say:] "Oh! That's interesting! We'll have a look at that!" Whereas you probably wouldn't sit in your lounge and think: "I need to find about*

> *Nemo...” So, because it was here, you made the effort to stop it. It was easy to stop and look and learn from it. (int. 3-V)*

Learning through interpreting the technology is mainly specific to visitors from an IT background:

> *Cause we both work in IT, so it’s fascinating for us to actually look at the interaction and the touch screen and how actually it works and what is behind what you are seeing on the screen... Hence, me flipping round the actual screens is to try to get more information around what you are actually using, what the coding is and stuff like that, concerning the music and the actual interaction with the items on the screen really. (int. 5-V)*

Learning through being in a social context included learning proactively by observing other people, learning passively by being approached by them to be taught, or participating in the community for interactive learning:

> *I saw a little kid that actively approached a stranger couple who was struggling to interact with The Great Barrier Reef to show them how to do it. (Obs. Sunday 22nd Sept)*

> *Overall, it seemed a collaborative space in which people (parents, kids, couples, friends, etc.) were teaching each other how to interact with the applications and sharing their discoveries about this interactive space. (Obs. Sunday 22nd Sept)*

5.3.3. Visitors’ Experiences of the Cube

As an aspect of the experience of learning in The Cube, visitors experience The Cube as (a) a technological space; (b) a learning space; or (c) a wall space.

A technological space is mainly an IT expert way of experiencing The Cube, in which people discern the underlying technical features of The Cube:

> *I’m trying to think what that program is... it’s not program X. But it’s like where you can bring up different screens and stuff like that which is just really quite awesome actually. And I’d look at something like that and see whether or not you could actually interact that with an information map outside when somebody is new to the area like we are, to come and be able to zoom in to certain points and zoom out and actually use that software to then look at restaurants and things like that. (int. 5-V)*

A learning space is seen as a whole, which is constituted of work spaces provided for visitors, in particular students working on their university projects:

> *During the time of observation (10 minutes for each application), no interaction occurred in front of the three applications (The Great Barrier Reef, Physics Playroom, ECOS). This is while The Cube had almost a busy time full of students, who were working with their own laptops or the computers available in The Cube. They were probably busy with their assignments. Some of them were working individually and the others in groups. They barely seemed to be paying attention to the applications (Obs. Wednesday 26th Sept)*

Table 3. The experience of learning in The Cube.

	High-level Managers "Intended Cube"	**Project Leaders "Enacted Cube"**	**Visitors "Experienced Cube"**
Ways of experiencing the object of learning	Intended learning objects • QUT expertise • STEM • Any random content When planning The Cube, what did you want people to learn?	Intended learning objects • Technology • Subject matter • Social interaction • Learning itself What did/do you expect people to learn in The Cube?	Actual learning objects • Technology • Content Have you learned anything today in this place? What have you learned?
Ways of experiencing learning strategies	Intended learning strategies • Acting as scientists • Appropriate intervention • Quality experiences When planning The Cube, how did you expect people to learn? When planning, what did you consider to be the key learning goals of The Cube environment?	Intended learning strategies • Technology • Scientific content • Teaching/learning styles How did/do you expect people to learn in The Cube?	Actual learning strategies • Intuitive interactive features • Interpreting the technology • Social context • Other Have you learned anything today in this place? How did you learn it?
Ways of experiencing the development of learning	N/A	Enacted learning strategies • Testing technology • Valid content • Exploit technological functions What did/do you put into place to help people learn in The Cube?	N/A
Ways of experiencing The Cube	• Technological artefact • Learning facilitator • QUT showcase • Public engagement hub	• Effectively designed complex system • Educational site • QUT showcase	• A technological space • A Learning space • A Wall Space (An isolated wall, Series of unconnected walls, Interrelated walls, Walls within a wider space)

A wall space is seen as an isolated and individual wall, a series of unconnected walls, interrelated walls, or walls within a wider space:

> *I like the three different ponds. The three different styles of information; like The Barrier Reef, and The Google with the flood information and the scientific sort of… It's not all on one content, if you like. It's not all one stream of information. I like the variety of walking around seeing different things. (int. 3-V)*

> *But it's also big enough, isn't it? That if there is some people doing it, you can see and learn from that and copy it on some other bit, you don't need to wait in a queue and [say:]*

> *"Oh! I'd like to have a go at that but there is no space to do it; because it's on a small scale or something". (int. 3-V)*

Table 3 is a complete version of Table 2 that combines the analysis, the interview questions and key elements of the findings.

6. Discussion

In this section, we consider what we have learned about the experiences of learning across the participant groups, and suggest future directions for further research.

6.1. Experiences of Learning across the Participant Groups

Here we explore: (a) what high-level managers and leaders expected visitors to learn, and what visitors actually learned; (b) the learning strategies that were intended for visitors, and what strategies were used; and (c) the similarities and differences in the ways the three participant groups experienced The Cube.

We were not able to compare how learning experiences were created, the "enactment" of intentions, because only one group, the project leaders, was involved in that phase of the work.

6.1.1. The Learning Objects in the Cube

Our phenomenographic analysis portrays both what high-level managers and project leaders intended visitors to learn, as well as something of what the visitors we observed and spoke to did learn. High-level managers had a broad picture of visitors learning about QUT expertise, especially research capability, learning about STEM research and gaining some form of personal enrichment from their experience.

Project leaders were focused on their own intentions, prioritizing learning about technology, specific subject matter, social interaction and learning itself. The first two of the project leaders' intentions aligned with visitors' lived experience, as visitors experienced learning in terms of technology and subject matter. While visitors certainly engaged in social interaction, we were unable to find evidence that they saw such interactions as something they learned about. Nor was there evidence of them learning about learning. Moreover, comparing the experience of managers and project leaders of technology, managers were more focused on visitors' learning about QUT technological capacity, while project leaders intended that visitors learn about technology itself. Concerning the content of learning, high-level managers intended visitors to learn about STEM-related content or "anything", and project leaders intended visitors to learn about accurate information, new concepts or subjects in school curricula.

6.1.2. The Learning Strategies in the Cube

The identified picture of learning strategies also shows that Cube high-level managers had an expansive vision of possibilities, around assisting visitors to act as scientists, possible interventions and providing a quality experience. Project leaders had a more focused and practical vision, associated

with using technology, presenting scientific content, and facilitating particular teaching and learning styles. The lived experience of the visitors clearly aligned with project leaders' intentions around using technology; they emphasized using the intuitive interactive features of the technology and interpreting the inner-workings technology. They also appreciated the importance of the social context, the need for interaction with others, as a learning strategy. Interestingly, while project leaders indicated they wanted visitors to learn about the value of social interactions for learning in high-end technical environments, evidence to date does not reveal them emphasising it as a planned learning strategy when asked to reflect on that aspect.

Together, the results show that project leaders' intentions significantly impact the enactment of the space, as much as or more than those of high-level managers. This may inform the management of the development of other such systems.

6.2. Future Directions

In this section, we discuss possible future directions for research in giant multimedia environments like The Cube. Apart from pursuing further insight into the early study findings through interaction with more participants, the research may be expanded in the following ways.

6.2.1. Exploring the Enacted Cube through Specific Projects

In this early study, we explored the experience of learning across five projects in The Cube. We adapted the phenomenographic approach to investigating classroom experiences of learning. One outcome of that was that the idea of the "enacted" cube became specifically tied to the notion that project leaders were "enacting" or implementing managerial plans and intentions. That implementation of the project leaders was clearly separated from the managerial plans, in the sense that it was undertaken by a different group of people. Hence, the enacted Cube itself can be said to have both intended and enacted aspects. The Cube scenario was thus clearly different from the classroom scenario where the same person, the teacher, is the person involved in both the intended and enacted aspects of classroom learning experiences.

A higher level of detail around learning strategies would be possible if the experiences of project leaders associated with specific projects were pursued to comprehensively investigate their intended and enacted experiences. This would also enable us to conduct a different kind of comparison with visitors' actual experiences.

6.2.2. Exploring the Necessary Conditions of Learning Using Variation Theory in Large Complex Educational Systems

Variation theory is the underlying theory of learning associated with the phenomenographic research approach used in this investigation.

The basic tenet of variation theory is that people's learning is determined by what they are able, or unable, to discern in the learning context. Based on that proposition, we suggest that learning environments are effective when they stimulate people to discern the critical features of systems.

Using variation theory, researchers can study interactions in technologically complex learning environments, to determine if the way the designers and developers stimulate variation in experience leads learners to become aware of critical features of the object of learning in ways intended by the designers and developers.

Marton [11] refers to this as attending to the "necessary conditions of learning". Focus on specific projects in high end technological environments such as The Cube allows particular attention to be focused on the technical features that make learning possible, paying special attention to those features that are being varied in each project to bring about learning. For example, in the physics project a range of physical concepts are taught by varying the gravitational context. A detailed investigation of variation in gravity and what makes it possible for learners to experience that variation, and therefore learn, is possible using phenomenographic methods.

While phenomenography has been used since its inception to identify what learners experience as varying, variation theory proposes four types of variation, that is fusion, separation, contrast, and generalization [11], which may be intentionally used by teachers to make learning possible. These four kinds of variation have been used by researchers to study interactions in classrooms to determine if a teacher's use of the types of variation in a lesson enables learners to become aware of the object of study in accordance with the teacher's intentions (e.g., [15,17]). We have shown in this project that phenomenography and the intended, enacted and experienced framework are able to reveal many aspects of the experience of learning in The Cube. This suggests that further refinement of the method, involving the application of variation theory, would also be possible.

Continuing to adapt and develop the phenomenographic approach for non-classroom contexts is likely to provide deep insights into the possibility of using variation theory to guide the development of large, complex educational systems.

6.2.3. Considering a Wide Range of Stakeholder Groups

Clearly there is potential for investigations of this kind to explore the value of giant interactive walls for the higher education institution—not just to showcase science, but also to bring about learning. This project has led us to see the importance of considering wider stakeholder groups, such as educators and curators, as well as the importance of differentiating between learner groups in such research. For example, we have become conscious that the visitors we spoke to, while engaged in the experience of learning, were not necessarily intentionally learning. It is potentially important to differentiate between learning populations that are intentionally and unintentionally learning in The Cube. Those intentionally learning may include students of school and higher education curricula, as well as other visitors. Formally enrolled students, like other visitors, might also experience unintentional learning.

7. Conclusions

Phenomenography has previously been used to explore learning experiences in classrooms, adopting an intended, enacted and experienced matrix around the investigation and analysis. In this project, we apply the principles of such research to a different learning environment: The Cube: Queensland University of Technology's giant interactive multimedia environment. We thus seek to

help designers and developers of this space to enhance a complex technological learning environment in order to enable more visitors to experience it in the way they intend. The present investigation, conducted in the first twelve months of The Cube's life, has revealed both variation within stakeholder groups and indicated alignment across stakeholder groups. This early work suggests that using a wider range of analytical tools of phenomenography to specific elements may enable future research at the whole-of-Cube level to yield deeper insights.

It also appears that similar studies could be conducted at the level of each project, or even specific sections of projects, which might model the "classroom studies" more closely. For example, in such cases, the project leaders could be the key respondents for both the intended and enacted aspects of the study, and visitors could participate in aspects of the study associated with the enactment and meaning they attribute to their experiences.

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Conflicts of Interest

The authors declare no conflict of interest.

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