Learning Experiences in a Giant Interactive Environment: Insights from The Cube

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Learning Experiences in a Giant Interactive Environment: Insights from The Cube

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Abstract
In November 2012, Queensland University of Technology in Australia launched a giant interactive learning environment known as The Cube. This article reports a phenomenographic investigation into visitors’ different experiences of learning in The Cube. At present very little is known about people’s learning experience in spaces featuring large interactive screens. We observed many visitors to The Cube and interviewed 26 people. Our analysis identified critical variation across the visitors’ experience of learning in The Cube. The findings are discussed as the learning strategy (in terms of Absorption, Exploration, Isolation and Collaboration); and the content learned (in terms of Technology, Skills and Topics). Other findings presented here are dimensions of the learning strategy and the content learned, with differing perspectives on each dimension. These outcomes provide early insights into the potential of giant interactive environments to enhance learning approaches and guide the design of innovative learning spaces in higher education.

Keywords
informal learning, immersive learning, giant interactive screens, learning spaces, QUT, The Cube, university visitors, university community outreach, phenomenography, public multi-touch displays, digital learning environments

Introduction
This paper explores the critical features of learning in a technologically advanced learning environment: The Cube. Hosted by the recently constructed Science and Engineering Centre of the Queensland University of Technology, Brisbane, Australia, The Cube has served since November 2012 as a learning environment for school and university students, staff and academics, as well as the general public. The Cube environment, referred to in this paper simply as The Cube, supports community engagement and is also used to connect school education with tertiary education (Rasmussen & MacKinnon, 2013). It demonstrates science and engineering principles, inviting users to interact with its large-scale, science-oriented interactive virtual environments. The interactive walls that are part of the Cube space indicate its expansiveness – 4 panels, 14m x 9m each, including over 40 interactive screens (https://www.youtube.com/watch?v=HTjjX5mW_aY).

Despite its name, The Cube does not have boxlike geometrical proportions – its very essence is fluidity, openness and multi-dimensionality (in terms both of physical presence and learning experience). It is expansive, rather than confining, and in many senses it is impossible to establish physical boundaries for it. As a result, there are varying interpretations of The Cube among its managers, its project leaders and its visitors. These include seeing The Cube as a showcase for QUT science and technology capabilities, as a public engagement hub, and as an educational site. Visitors also see it as varying configurations of the digital wall applications: a single application, a series of unconnected applications or a series of interrelated applications (Sayyad Abdi, Bruce, and Stoodley 2014). Although the digital walls do not by themselves constitute The Cube, the results of our previous study suggest that these applications sit at the heart of the experience of
visitors. From our perspective, in addition to the giant, interactive, multi-touch screens, The Cube also encompasses physical social learning spaces, for example group workrooms and breakout areas.

At the time of our observations and interviews, visitors had access to applications via the giant screens representing the Great Barrier Reef, physics concepts around gravity and a community wall representing Brisbane flood zones. Since then, new applications have been developed, in particular associated with chemistry and astronomy.

Other researchers have considered people’s use of large interactive displays (e.g. Peltonen et al., 2008; Duarte et al., 2012; Rönneberg, Sarjakoski, and Sarjakoski, 2014; Rittenbruch, 2013). However, relatively few research-based insights have been offered into learning associated with large interactive environments. In their study of a prototype multi-touch display, Morgan and Butler (2009) theorised that multi-touch screens could facilitate high degrees of collaboration, and therefore learning, in classroom and other contexts. In another study, Rick et al. (2009) found that exploration and creation are key learning activities that multi-touch interfaces effectively support. Both these studies were conducted in formal classroom spaces.

Previous research has tended to take a skills-oriented view of what makes users capable of interacting with multi-touch systems. For example, Hornecker (2008) investigated how people in a museum learned how to interact with a multi-touch table. In contrast, our investigations examine the experienced meaning of learning at a broader level.

Our first study, conducted within the first twelve months after The Cube was opened to the public, explored learning in The Cube from different stakeholder perspectives: high level managers of The Cube project designers and developers of The Cube, and The Cube visitors (Sayyad Abdi, Bruce, and Stoodley 2014).

In this paper we report the findings of a new study completed in the second year of The Cube, which focuses entirely on the experience of visitors. The findings presented in this paper extend and deepen our early understandings of visitors’ learning experience. With a focus on content learned and learning strategy, we have developed a detailed picture of visitors’ critically varying experiences of learning in The Cube.

Our study was conducted using phenomenography. Phenomenographic researchers are interested in variation in experience (Bruce 2011). Learning from a variation theory perspective, which has emerged from phenomenography, is about coming to see things differently (Marton and Booth 1997).

It is anticipated that interactive environments such as this will become increasingly employed to stimulate learning. As a result, we believe that our findings about variation in learning in The Cube have the potential to influence future learning innovations and to disrupt our understanding of what it takes to learn in innovative learning spaces, particularly those spaces that feature interactive screens like The Cube. Furthermore, the insights here contribute to the evolving trajectory of phenomenographic studies into learning. While many phenomenographic studies focus on formal curriculum-based learning of enrolled students, this study explores informal learning in digitally enriched community spaces associated with a university.
Research Approach
Phenomenography is well established and suited to understanding variation in the experience of phenomena (Marton and Booth 1997; Marton 2014). The phenomenon we investigated was visitors’ experience of learning in an interactive learning space featuring giant digital interactive walls.

Learning, according to variation theory, is about becoming aware of aspects of the world that have been previously undiscerned, resulting in a greater variation of experience (Marton and Booth 1997; Bowden and Marton 1998; Marton 2014). A learner may then hold one or more perspectives in simultaneous awareness and is able to apply the perspective(s) relevant to their circumstances. Thus, the findings we present in this paper focus on variation, including its inherent dimensions, which may assist Cube learners to expand their awareness (Marton 2014).

The phenomenon under investigation here follows early phenomenographic tradition (e.g. Marton and Säljö 1976; Entwistle and Ramsden 1983) of exploring the experience of learning from the perspective of different stakeholders, with the key difference that in this context learning is not of the formal academic kind. Rather, it considers an informal approach to learning that is social and self-directed, where The Cube visitors are intrinsically motivated to learn outside the education system and without the constraints of an officially imposed curriculum (Falk and Dierking 2002; Livingstone 2001). The Cube is a site that intentionally opens up learning opportunities, rather than focusing on specific content or artifacts. Thus, multiple content areas from diverse disciplines such as physics, biology and environmental engineering may be simultaneously available, and approaches to learning are similarly not controlled. The visitor-learners themselves choose to attend to particular aspects of content and adopt particular learning strategies.

As an example of new and disruptive technology, it is important to understand how learning is experienced in spaces such as this, both to illuminate the character of the learning experience and to explore the potential of phenomenography as a research tool in such environments.

Gaining Insight into Visitors’ Learning Experience
To understand visitors’ experience of learning in The Cube we observed visitors and conducted brief interviews. The participating visitors reflected a diverse population, including tourists, university students, families with children and technology professionals. Although we focused on adults and did not interview children, parents often spoke about their children's experience, or directed the interviewer’s attention towards what their children were doing. In order to limit the time commitment for the interview participants, and reflect the informal nature of the environment and interaction, biographical details were not elicited.

We observed a wide group of people (number not counted), and interviewed 26 male and female visitors. Observations involved members of the research team watching people in The Cube from a distance, on weekdays and weekends, in blocks of approximately 30 minutes, over the course of two months. The observers noted activities occurring in the space such as visitors’ motions, gestures, reading and viewing of others. The observers followed observation guidelines established in the previous initial study of multiple stakeholders: What spaces are being used? How are these spaces being used and what is
occurring there? What appears to be informing the visitors? What learning appears to be occurring? (Sayyad Abdi, Bruce, and Stoodley 2014, 6)

Interviews engaged visitors in brief conversations about their learning experience. In order to maintain consistency with the earlier study, the same interview questions were adopted: Why are you visiting The Cube? Have you learned anything today in this place? What have you learned? and How did you learn it? (Sayyad Abdi, Bruce, and Stoodley 2014, 7). The questions were intended to open up the phenomenon of learning as it was experienced, and to encourage participants to provide concrete examples of what they had learned, as well as how they learned those things. The open nature of the questions also helped the interviewing researcher(s) avoid making assumptions about the experience of the participants (Åkerlind 2005). In common with most semi-structured interviews, further prompting questions were asked as required, for example, “Can you tell me more about that?” and “Can you explain that in a different way?” The interview conversations, typically 5 to 10 minutes in length, were transcribed verbatim.

**Forming Descriptions of Learning Experience**
Observation notes and conversation transcripts were explored iteratively to discern critical variation in visitors’ experience of learning in The Cube. In keeping with the phenomenographic approach, visitors’ learning experience was investigated in terms of:

- The content learned (or the learning object); and
- The learning strategy (or how learning happened).

The learning experience, developed in the form of categories, is presented below. Each category describes the experience in terms of its meaning, along with a ‘theme’ (those elements that visitors directed their immediate attention towards), a ‘field’ (the elements surrounding the theme that visitors considered relevant) and a ‘margin’ (the elements that visitors did not attend to). Each category also illustrates the experience with indicative quotes from interviews and observation notes. Interview quotes in the following categories are identified by the code I and the interview number, and the observation references are identified by the code obs and the date of the observation. Variation across the categories is identified in terms of shifting foci, and differing elements associated with the field and margin. Variation is also highlighted in terms of dimensions, which span the content learned and the learning strategies. The dimensions operate across all categories and no one dimension is associated with any one category. Additionally, alternative perspectives on each dimension are reported.

As we progressed in the analysis, we discovered critical variation in visitors’ experience of the **learning space** (i.e. The Cube) itself, which frames their learning experience. These are not presented as full categories with theme, field and margin, because the space itself was not the main focus of our study. However, in order to present an overview of the context of the phenomenon, we include visitors’ experience of the learning space in the findings.

In summary, we first present the main findings as a set of categories that describe visitors’ various experiences, concerning their learning strategies and the content they learned. These are accompanied by a description of different dimensions in visitors’ experiences across the categories, which identify key aspects that make a difference to the quality of learning. Finally, we present an overview of the visitors’ experience of the learning space.
Visitors’ Experience of Learning in The Cube Space
We have identified the following learning experiences that demonstrate visitors’ experiences of learning strategy and the content learned, including their varying dimensions. Taken together, they comprise the experience of learning in The Cube:

• Visitors’ experiences of learning strategy:
  o Learning strategy is experienced as absorption
  o Learning strategy is experienced as exploration
  o Learning strategy is experienced as isolation
  o Learning strategy is experienced as collaboration

  The varying dimensions in the experience of learning strategy:
  o Engagement
  o Scope
  o Affect
  o Awareness

• Visitors’ experiences of the content learned:
  o Content is experienced as technology
  o Content is experienced as skills
  o Content is experienced as topics

  The varying dimensions in the experience of content learned:
  o Depth
  o IT systems
  o Interactions

In the following, the constituent elements of the structure of each category are presented in a table after each group of categories are discussed.

Visitors’ Experiences of Learning Strategy
Visitors experienced learning strategy, or how they learned in The Cube, in four different ways, as: Absorption, Exploration, Isolation and Collaboration. These form contrasting pairs – Absorption-Exploration and Isolation-Collaboration.

Category 1: Absorption
In this experience, visitors saw learning as a process of storing sanctioned knowledge in their memory banks. They experienced learning as informed by an external source of reliable knowledge. This was expressed as being intuitive when already understood features were used without reflection, or it was referred to as recalling when already stored knowledge was resurfaced:

  M1: we are engineers. It’s refreshed memories of certain things, what I’d learned years ago. M2: Reminded me of the periodic table, though I remembered a fair bit. (I13)

Category 2: Exploration
In this experience, visitors saw learning as a process of trial and error. Knowledge was discoverable by them or was something they had the capacity to create. When seeing
learning in this way, visitors engaged actively and often playfully with The Cube and chose to follow leads that interested them:

    Just getting in there and doing it. Just by having a go. Cause there are no instructions around, so you just get on up and you just give it a go and you just start working with it. So, just by getting in there and doing it. (I9)

Category 3: Isolation
In this experience, visitors saw learning as an individual endeavour, they didn’t consider learning as happening in association with others. The visitor understood learning as working alone, concentrating on specific detail:

    If I was here on my own, I might be able to look at the detail but no, I haven’t really learned anything here today. (I17)

Category 4: Collaboration
In this experience visitors saw learning as a process of collaboration through communication with others. This communication may be direct, by talking with others or engaging in an activity with them, or indirect, by observing others. Visitors experienced collaboration as enabling them to advance rapidly in their learning.

    This one here [the Physics wall] I didn’t know exactly what was going on until I overheard someone talking about the gravity stuff. Then you think, “Ah, OK, you’re simulating planets”. (I13)

Structure of the Categories
The structure of the categories that describe visitors’ experience of learning strategy is presented in Table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Theme (focus)</th>
<th>Field (associated concepts)</th>
<th>Margin (not attended to)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption</td>
<td>Internalisation – accepting external validation e.g. embracing sanctioned knowledge</td>
<td>Instruction, established knowledge</td>
<td>Exploration</td>
</tr>
<tr>
<td>Exploration</td>
<td>Experimentation – using trial and error e.g. attempting new experiences</td>
<td>Play, creation, following interests</td>
<td>Absorption</td>
</tr>
<tr>
<td>Isolation</td>
<td>Concentration – focussing on detail e.g. choosing the information tab</td>
<td>Reading text</td>
<td>Collaboration</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Communication –</td>
<td>Observation,</td>
<td>Isolation</td>
</tr>
</tbody>
</table>
Dimensions of the Experience of Learning Strategy

Visitors experienced learning strategy (i.e. how they learned in The Cube) from the different perspectives, or dimensions, of Engagement, Scope, Affect and Awareness. For example, as shown in Table 2, they engaged in learning passively or actively. Similarly, they were aware or unaware of learning that occurred in the Cube.

Engagement: Engagement refers to individuals’ differing degrees of investment in their learning. From one perspective (passive), visitors’ engagement was in the form of observing others’ activities, for example looking at how children interacted with the walls or looking at the wall’s animation without interacting with it.

I just quickly had a look. But it was watching other people playing with it as well, and realizing that if you touched a planet the slide board changed (I15)

In the alternate way (active), visitors touched the walls and interacted with the projects, for example making various kinds of fireworks and sending them up into the sky.

you don’t know what’s in fireworks, you watch them every year but you have no idea how they are made. And it’s just good fun trying different things and seeing what happens. And to see what happens when you know things aren’t going to work but what happens when you use them, anyway. Without blowing yourself up. (I16)

Scope: Scope refers to the breadth of visitors’ view when learning. From one perspective (close focus), visitors paid attention only to the wall immediately in front of them, for example selecting planets on a panel where they were standing.

in front of the Great Barrier Reef, adults were fascinated by the whole thing, while kids were only focused on how they could interact with the screen. (Obs 22/09/14)

In the alternate way (panorama), visitors took in the whole wall, for example looking at what others were doing and seeing the effect that had on the rest of the wall.

initially when I was watching the kids, the kids were getting a kick out of throwing things in the air. I went away and came back and saw the effect was not so marked, so I realized that something had changed and it took me a while to work out that someone was influencing the amount of gravity that was having an effect on the way things travelled. So I went searching for how they did that. (I12)

Affect: Affect refers to the attitude of the visitor. From one perspective (serious), visitors adopted a resolute attitude and interacted with the space with intention, for example reading specific text to gain knowledge.

if you put things in front of them that are fun, they will play and hopefully understand and by talking to them about the things they see, they do learn a little bit as you do it.
But I think someone needs to be talking to them as they play otherwise it’s just play, to them. I don’t think they pick up that Pb is lead and what it is. (I15)

In the alternate way (fun), visitors were interested in playing, for example manipulating the wall elements or exploring to find what they were able to do.

We’ve just learned about what’s the best fuel in rockets. We’ve learned about what makes the best fireworks. It’s been good fun! … We just tried different things. Then we had a competition between four of us and tried different things and saw who won. It was good fun. (I16)

Awareness: Awareness refers whether or not visitors were aware of the fact that they were learning. From one perspective (unaware), visitors did not identify any learning through The Cube although they had indeed learned while interacting with it.

I: Have you learned anything here today? M1: Probably not, we are engineers. It’s refreshed memories of certain things, what I’d learned years ago… [Later] M1: The other thing I noticed was you can press on the information thing and it’ll talk about inventors… [Later] M1: I read a little bit. There are a number of characters I didn’t know about… (I13)

In the alternate way (aware), visitors were able to identify specific learning through their interaction with The Cube.

We’ve just learned about what’s the best fuel in rockets. We’ve learned about what makes the best fireworks. (I16)

Table 2: Dimensions of Cube visitors’ experience of learning strategy

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Alternate Perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>Passive – low engagement e.g. watching others</td>
</tr>
<tr>
<td>Scope</td>
<td>Close focus – parts e.g. looking at the detail</td>
</tr>
<tr>
<td>Affect</td>
<td>Serious – intentional, intense e.g. reading the text in detail</td>
</tr>
<tr>
<td>Awareness</td>
<td>Unaware - learning is a by-product e.g. playing with rockets teaches about fuel mixes</td>
</tr>
</tbody>
</table>

*Visitors’ Experiences of the Content Learned*

Visitors experienced the content learned, or what they learned in The Cube, in three different ways, as: Technology, Skills and Topics.
**Category 1: Technology**
In this experience, visitors learned about the technology of The Cube (its hardware and software). They noticed the way The Cube system was constructed and were interested in the code that made it operate. Often, this was with a view to extending their own technological expertise or to applying the same idea in their own situation:

> 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 we are seeing on the screen... Hence, me flipping round the actual screens to try to get more information around… what the coding is (I5)

**Category 2: Skills**
In this experience, visitors learned about the skills needed to make The Cube work. They built their ability to manipulate the wall projects, so they could explore them or play with them:

> An observee was using his fingers to zoom in on the Google map on the Flood Map (like as he did when zooming in and out on an iPad). He did not get any success. He gave up and stepped back. Suddenly he noticed the zooming buttons and tried again. He succeeded and continued his interaction. (Obs 22/09/2013)

**Category 3: Topics**
In this experience, visitors learned about the subjects presented on The Cube walls. They increased their knowledge and experience of the topic displayed:

> I was learning about the striped snapper, because I wasn’t quite sure what they were… I was learning about the different clams, the different fish and animals that I didn’t know about before. (I2)

**Structure of the Categories**
In addition to the differences in meaning associated with what was learned, we identified differences in the theme, field and margin for each category. These are presented in Table 3, showing how these differ across the categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Theme (focus)</th>
<th>Field (associated concepts)</th>
<th>Margin (not attended to)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>IT</td>
<td>Hardware, software,</td>
<td>Topics</td>
</tr>
<tr>
<td>Skills</td>
<td>Making The Cube work</td>
<td>Touch, gestures, functions, features</td>
<td>Topics</td>
</tr>
<tr>
<td>Topics</td>
<td>Subject matter</td>
<td>Wall projects</td>
<td>Technology</td>
</tr>
</tbody>
</table>

**Dimensions in the Experience of Content Learned**
Visitors experienced content, or what they learned in The Cube, in differing ways, with regard to Substance, Technology and Interactions. For example, Table 4 shows the dimensions of experience of Depth as Simple and Complex.
Depth: Depth refers to the nature of what was learned. In the first way of experiencing depth (simple), it has to do with superficial learning about straightforward, factual information, for example names or basic information about artefacts in The Cube projects:

I learned some things about some of the animals in The Great Barrier Reef… Fish names, species… (I10)

The alternate way (complex), involves deeper learning about complicated interrelations in the worlds represented in The Cube, as well as their impact on the visitor:

My youngest son was just starting to appreciate... that the objects would continue to move until they were stopped by something. This wasn’t related to gravity pulling them down but when they were being pulled horizontally that they would continue to move. He was starting to work out that that wasn’t normally the way things happen. (I12)

IT Systems: IT Systems refers to what was learned about the hardware and software of The Cube. In the first way of experiencing IT systems (IT configuration), the technological elements that make up The Cube are prominent:

We looked on the inside as well. That was really cool. All the computers and… membrane of it… how it all fitted together, all the touch screens and how they interlocked and how they’re controlled by just one… (I10)

In the alternate way (IT use), the usefulness of technology to help people learn is in view. For example, technology’s responsiveness to touch engenders interaction and large-scale displays enable collaborative learning:

I’ve actually come to look at the different levels of how you’ve done what you’ve done and what I could use within our [teaching] scenario… (I16)

Interactions: Interactions refers to the abilities visitors gained in The Cube. In the first experience of interactions (others’ interactions), other people’s abilities are discerned:

What I’ve learned is more about how my children respond to things and that if you put things in front of them that are fun, they will play and hopefully understand and by talking to them about the things they see, they do learn a little bit as you do it. (I15)

In the alternate way (personal interactions), their personal abilities are in view:

I guess I’ve learned how it works. How to interact with the maps, because I didn’t know how to do that. That only took a second. (I10)

Table 4: Dimensions in Cube visitors’ experience of the content learned

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Alternate Perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Simple - superficial characteristics e.g. knowing fish names</td>
</tr>
</tbody>
</table>
gravity dynamics

<table>
<thead>
<tr>
<th>IT systems</th>
<th>IT configuration - the mechanical nuts and bolts e.g. how the technology is configured</th>
<th>IT use - the purpose of the technology, e.g. how it is useful to stimulate learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactions</td>
<td>Others’ interactions - how others use the walls</td>
<td>Personal interactions – how they use the walls</td>
</tr>
</tbody>
</table>

Visitors’ Experiences of the Cube Learning Space

Our understanding is that visitors’ experience of The Cube itself, as the context of learning, is intimately related to their experience of learning. Visitors experienced The Cube in terms of Reality, Familiarity and Stimulus.

**Reality**

Visitors linked their experience of The Cube with the real world in differing ways. On the one hand, visitors considered The Cube directly represented the physical world:

> You can through trial and error get something to happen but in reality I’m not sure that you would be wanting to sending up millions of dollars of equipment on trial and error, you’d probably want a bit more certainty than that. (I14)

Alternatively, visitors considered The Cube offered a virtual reality which mirrored the real world, but without its constraints:

> It’s just good fun trying different things and seeing what happens. And to see what happens when you know things aren’t going to work but what happens when you use them, anyway. Without blowing yourself up. (I16)

**Familiarity**

Visitors responded to The Cube differently in terms of the familiarity of the features. On the one hand, visitors may find the environment normal and intuitive:

> I suppose it would be strange if it would not be a touch screen. Now every day and every screen, you would expect it to be touchable. (I11)

Alternatively, visitors were surprised and excited by aspects of The Cube they did not expect:

> I liked the way it interacts and you don’t expect them to go into the big screen. (I16)

**Stimulus**

Visitors responded to the stimulus offered by The Cube differently. On the one hand, visitors explored within The Cube environment, to find all The Cube itself had to offer:

> I think if you went around you could learn about each of the chemicals and the compounds quite easily... there’s heaps of information... When you press on the table... that element comes up and then you can learn a little bit about that element. (I16)
Alternatively, visitors explored beyond The Cube environment, following links to sources outside The Cube:

Using the QR scanner thing on the phone as well to go and look at the website and see if there is any more information. (15)

**Discussion and Implications**

The Cube demonstrates QUT’s innovative focus and technological capacity. It offers rich opportunities for self-directed informal learning in a social context (Falk and Dierking 2002; Livingstone 2001). However, its potential to enhance learning and teaching across the university is still unrealised. The virtual worlds it creates are presently connected with formal curriculum in a limited way. As we anticipate technologically-driven future learning, it becomes important to consider how such spaces can make significant contributions to all learner experiences and outcomes.

Currently, visitors’ learning in The Cube is largely informal. In presenting a nuanced picture of how visitors experience learning in The Cube, this study’s findings identify a new kind of learning community that forms organically around The Cube. These findings provide insights that may inform the design and use of giant interactive walls for both formal and informal learning.

**Variation and learning in The Cube**

According to Variation Theory, an understanding of learners’ experience of learning strategy and the content of learning is integral to effective learning design (Marton and Booth 2007; Marton 2014). Good educational design is understood to stimulate an expansion of the learner’s awareness.

The Cube visitors’ experience of learning strategy (i.e. How they learn in The Cube) may be understood to lie across two continua of expanding awareness, from Absorption to Exploration and from Isolation to Collaboration, towards increasing agency and community. This may be viewed as an overarching continuum of increasing self-confidence.

Learners experiencing learning as Absorption expect others to determine what is worth learning, whereas learners experiencing learning as Exploration see their own choices as integral to their learning. Thus the expanding awareness evidenced in moving from Absorption to Exploration may be understood in terms of increasing agency. In other words, as their awareness expands, learners more confidently manage their own learning through personal choices.

Learners who experience learning as Isolation pursue learning as an individual enterprise, whereas learners who experience learning as Collaboration include other people as essential to learning. Thus the expanding awareness evidenced in moving from Isolation to Collaboration may be understood in terms of increasing appreciation of community. In other words, as their awareness expands, learners more readily include interaction with others.
All of the dimensions of visitors’ experience of learning strategy (Table 2) run across all of the categories. It remains to be seen if some of the dimensions’ perspectives sit more naturally in certain experiences of learning than others; for example, the Absorption-Exploration continuum would seem to have affinity with the Engagement dimension’s Passive-Active alternatives. Light may be shed on this in future research.

The variation in learning strategies, illustrated in Tables 1 and 2, indicates the need for designers of facilities like The Cube to provide a space in which people with a limited repertoire of learning strategies may encounter those strategies. For example, those people who only discern an Absorption strategy in this context will not make use of features catering to the other learning strategies. Thus, for visitors using the Absorption strategy, information from sources they perceive to be authoritative needs to be accessible and for the visitors using the Exploration strategy multiple pathways for engagement are required.

Spaces like The Cube, according to Variation Theory, are likely to be most effective as learning environments when designed to stimulate encounter with variation. As people meaningfully encounter alternative, as yet unappreciated, learning strategies, they are prompted to learn about alternative strategies and subsequently embrace more effective or varied approaches to learning. For example, a person adopting an Absorption approach to learning may be prompted to intentionally apply a new method, such as Exploration.

Additionally, when people are aware of multiple perspectives (e.g. both Absorption and Exploration strategies), they adopt the perspective that is relevant to their immediate circumstances. They may alternate rapidly between these perspectives as their apparent relevance changes. Thus, for facilities such as The Cube to be effective learning environments, they should enable rapid shifts between alternate perspectives.

Similar observations about variation may be made concerning Cube visitors’ experiences of content summarised in Tables 3 and 4. Thus, in order to provide a rich learning environment, stimulus towards the breadth of possible strategy and content experiences should be present. The results of this investigation provide a schema for identifying core experiences necessary for learning, and thus focal points for the development and refinement of installations like The Cube if their usefulness as learning facilities is to be maximised.

**Identifying The Cube Community**

In order to extend the learning potential of The Cube, it is necessary to first understand how learners interact with it. The findings of this phenomenographic study reveal that although the learning context is informal, the experience of learning in The Cube is complex. Moreover, The Cube learning community is quite different from the traditional classroom or even university community.

The Cube’s learning community is essentially transient and diverse. It continuously forms and re-forms organically. It encompasses learners from inside and outside the university. Cube community members experience learning in The Cube in widely varying ways. For example, some may interact with The Cube as part of a formal learning activity, others may glance casually at it as they pass by and yet others may visit recreationally. Moreover, we noticed that within these groups visitors approach learning differently, for example some visitors intentionally engage in formal or ‘serious’ learning, while others learn incidentally while ‘playing’ with the wall applications. The purpose of this current study,
however, was to study the community as a whole and categorise experiences rather than compare the learning of specific groups or individuals.

As The Cube community and The Cube itself are constantly changing, the associated learning experiences are diverse. Our findings highlight the variety of learning experiences that occur in such a social learning space. Visitors learn by interacting with the walls, as well as each other through conversation and observation. In this way, learning becomes visible and tangible in new ways as visitors simultaneously experience the conceptual and physical elements of a phenomenon. They may not see critical features unless these are pointed out to them by others with a different physical vantage point. For example, at the Physics Wall a visitor might change the planet contextualising the wall from a high gravity to a low gravity planet; and only other visitors standing away from the wall will notice the resulting changes.

**Challenges and Opportunities**

The findings presented here highlight significant implications for the design of virtual and physical learning environments. Contemporary learners – like Cube visitors – bring a range of knowledge, expectations and approaches that extend beyond traditional educational horizons. Contemporary pedagogy embraces a range of learning experiences, technologies and spaces that cater for diverse learners across varied contexts (Johnson et al. 2015).

While the diversity and transience of learners enriches The Cube learning community, they pose significant challenges for designers of learning experiences and learning environments in spaces such as The Cube. These challenges call for flexibility and imagination in designing interactive technologies that intentionally enhance learning, rather than simply (re)developing functional virtual educational environments that address pre-determined curriculum requirements. These innovative technologies should not only support established ways of learning but also enable discovery of productive new ways to learn. For learners, educators and designers, this requires continuing exposure to latest technologies, and communication with others.

The results of this study show that visitors are not always aware of their learning. We suggest people do not see themselves as learning because they conceive of learning in traditional ways – we need to help break down this barrier to release people to learn in ways that seem new to them. Thus, we need to not only provide opportunity to learn but also challenge people's conception of learning.

**Further Research and Conclusion**

This work has provided some insights into visitor learning in The Cube, which have implications for the design of immersive environments such as The Cube and the learning spaces around them. Most importantly, it remains to consider how the identified variation in The Cube visitors’ learning experience should influence the design of learning in The Cube and similar environments. In addition, development of spaces such as The Cube open up many possibilities for further research, including inquiry into:

- How do physical spaces associated with giant interactive multi-touch displays need to be designed, to maximise learning opportunities?
- What further principles are required for learning design of immersive environments?
- How can such spaces be integrated into formal curricula?
• How can the use of such environments and spaces be maximised, to ensure learner connectivity?
• What role do the learner and teacher conceptualisations of such spaces play in influencing how they learn and design for learning in them?

In this paper we have explored the experienced meaning of learning in an innovative technological space: a configuration of giant interactive walls hosting virtual learning environments that enable people to experience concepts from physics, chemistry and biology. It has become apparent that learning in such environments happens both at the individual level and collectively, with collective learning sometimes required to gain the most from experiential learning. We have also seen that people may articulate changes in their experience of some aspect of the content, while at the same time not recognising that change of experience as learning. This may be a result of the influence of dominant interpretations of learning involving reading, text and engaging with discrete artefacts.

The variation in the learning experience in The Cube suggests the need for proponents of giant interactive walls to carefully embed learning opportunities into technological innovation. Advanced technology like The Cube is likely to achieve the greatest educational impact (and return on investment) when its design is underpinned by informed understanding of the whole community that will use it to learn.

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