
Title	Design and implementation of a student-generated virtual museum in a language curriculum to enhance collaborative multimodal meaning-making
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Source	<i>Computers & Education</i> , 57(1), 1083-1097
Published by	Elsevier

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Design and implementation of a student-generated virtual museum in a language curriculum to enhance collaborative multimodal meaning-making

Abstract

This paper reports on a study, *MUSE*, which involved Secondary (Grade 7) students in designing and constructing a virtual museum. It presents a description and evaluation of the design and implementation of the technologically-mediated intervention within a language curriculum that emphasizes multimodal meaning-making and expression. Participants' gallery artifacts, interviews, reflections and classroom observations indicated signs of an emergent multimodal awareness with a growing sensitivity to semiotic affordances and constraints. Collaborative learning skills acquired and language learning motivational gains were evident. The investigation identified responsive, adaptive measures in overcoming unanticipated challenges arising from on-the-ground realities and contextual constraints. The study showed the viability, to a certain extent, of innovative technologically-enhanced, museum-based interventions in reinforcing instructional pedagogy in classroom contexts.

Keywords: Applications in subject areas; Multimedia/hypermedia systems; Secondary education; Virtual reality

1. Introduction

In schools, traditional, print-based notions of literacy are giving way to the innovative ‘design’ of meaning-making (New London Group, 1996) in multimodal ways (Cope & Kalantzis 2001; Doering, Beach & O’Brien 2007; Miller, 2008) in line with the New Literacies (Barton et al., 2007; Gee 2008; Street 2008) movement. Essentially, these new forms of literacies emphasize multiple modes of meaning-making and representation (Jewitt 2008b; Kress 2000; van Leeuwen & Jewitt, 2001). Interactive digital media and rich semiotic resources (Jewitt, 2006; Kress 2000) that include audio, visual, spatial, tactile modes for meaning-making actively engage learners through encouraging experimentation, exploration and discovery.

One realization of this is through museum-based learning (Christal et al., 2001; Jackson & Adamson, 2009; Prosser & Eddisford, 2004) with activities mediated through or based on related museum learning experiences, a concrete instantiation of New Literacies in offering an informal, inquiry-driven learning (Dewey, 1938, 1991; Kuhn, Black, Keselman & Kaplan, 2000; Vavoula et al., 2009) through active participant engagement. The belief is that ‘education should begin with experience – with doing and interpreting objects’ (Hein, 2006, p.viii) that establishes connections to individuals, their ideas and experiences. Learning within a dynamic environment (Johnson et al., 2003) is activated through engagement with various stimuli through specially created museum platforms in the range of digital technologies for learning (Barak et al., 2009, Lemmens & Vanstappen, 2010; Meluch, 2009; Prosser & Eddisford, 2004). With technological mediation, this has extended the boundaries of learning even more, and enhanced the process of information sourcing, communication and documentation (Hsi, 2002). As a result, distinctions are becoming blurred between the real and virtual, sharpening the processes of inquiry and learning, and enhancing participant collaboration and exchange.

In Singapore, the Ministry of Education research and development program for interactive and digital media (IDM) aimed to study the use of IDM-based learning environments, tools and media to bring about engaged learning for students, and promote learners' 'critical appreciation of the multi-modalities of representation in IDM and their assimilation of IDM-based design and content-creation skills' (Foo, 2008, p.90). This was aligned with the government strategic focus on 'making learning come to life with multimedia and interactive elements' (IDA iN2015 Steering committee report, 2010, p.22) as laid out in the ten-year, national ICT Master plan, The Intelligent Nation 2015(IDA iN2015, 2010).

In line with the national objectives, this paper describes an innovative student-generated virtual museum project, *MUSE*, in the context of a language curriculum. The study involved teenage students in the design and construction of a virtual museum to represent their personal and cultural identity as young people in Singapore using a range of semiotic (meaning-making, Kress, 2003) resources- visual, audio, text, digital, virtual and/or augmented reality, real life stimuli and a combination of these. The general objective of *MUSE* was to enhance students' multimodal awareness, develop their imaginative, creative skills and overall adaptive capacity for designing meaning, receptively and productively, in multimodal contexts. The aim of this paper is to examine the design and implementation process and study the impact of the research intervention within a specific school context. This study contributes to a growing interest in examining how the affordances of museum-based, digitally-mediated learning environments can be harnessed effectively to impact teaching and learning.

Earlier studies of technologically-enhanced museum learning in various contexts encompassed development of different technological platforms, tools and resources to support learning. These ranged from web-based platforms and resources (Barak et al., 2009; Eakle,

2009), mobile devices (Abowd et al., 1997; Hsi, 2002; Papadimitriou et al., 2006; Reynolds, Walker & Speight, 2010; Vavoula et al., 2009) to virtual and augmented (Müeller-Wittig, Zhu & Voss, 2007; Song, Elias, Müeller-Wittig & Chan, 2005; Song, Elias, Martinovic, Müeller-Wittig & Chan, 2004) tools. However, there remains a dearth of investigations into documented research in educational contexts which involves predominantly student-generated design and content for virtual museums constructed primarily *by, for* and *with* young learners themselves as a multimodal construct of their youth culture with the attendant beliefs, values and interests. Also, many of the available studies were primarily overseas-based with relatively older participants. This study, in adopting an interventionist design research (Collins, Joseph & Bielaczyc, 2004) approach to the construction of a virtual museum by early adolescents within a specific pedagogic context to fulfill targeted curricular goals, fills a gap in current educational research, particularly in the local research and pedagogic contexts in this region and beyond.

2. Theoretical underpinnings

2.1. Constructivist, inquiry-driven, collaborative learning environments

The study is aligned with constructivist (Bruner, 1993; Jonassen, Peck & Wilson, 1999; Papert, 1993, 1994; Von Glasersfeld, 1987, 1995a, 1995b) learning principles through different modes of knowledge representation and interactive, digital media for collaborative knowledge construction, drawing on students' experiences and interests. It acknowledges that 'people construct new knowledge with particular effectiveness when they are engaged in constructing products that are personally meaningful' (Resnick, 1997, p. 23-24).

As an inquiry-driven (Dewey, 1938, 1991; Kuhn, Black, Keselman & Kaplan, 2000) form of learning, students in this study direct their own investigatory activity, and 'formulate

questions, plan their activity, and draw and justify conclusions about what they have learned' (Kuhn et al., 2000, pp. 496–497). Learning as a socially-mediated process with Vygotskyian (1978) roots where learners are responsible for their learning is central in sociocultural design (Vygotsky, 1978; Wertsch, 1991). Each individual constructs his/her own meaning and learns through collaboration and interaction with others within authentic communities of practice (Wenger, 1998). This is prominent in museum learning literature as a framework for research (Ellenbogen, 2003; Leinhardt, Crowley & Knutson, 2002).

2.2. *Multiliteracies and multimodal meaning-making*

Meaning-making anchored within the multiliteracies perspective of the New London Group (1996) involves 'the purposeful integration of semiotic resources' (Vaish & Towndrow, 2010, p.321) where the various modes interplay with each other through how they 'are combined and designed to make meaning' (Baldry, 2001; Kress & van Leeuwen, 2001) such that the 'whole (becomes) far greater than the simple sum of its parts' (Lemke, 1998, p. 284). In studying the 'design of meaning' (New London Group, 1996) whereby people 'make use of the resources that are available at a given moment in a specific communicational environment to realize their interests as sign makers' (Jewitt, 2008b, p.253; cf. Kress, 2003), this foregrounds learners' creative, adaptive capacity in using semiotic resources to construct meaningful knowledge through multimodal representations.

Central to multimodal studies of meaning-making is an object-oriented focus (Hein, 2006, Sheppard, 2002) which foregrounds a visually-oriented learning (Jewitt, 2008a; Smith & Woody, 2000). Visuality (Lister et al, 2008) emphasizes vision as 'an active, interpretative process' (Wood 1996, p. 68). Participants' constructs of visual representations concretize their experiences, beliefs and values in a dynamic way. Current research (Seitz, Kim & Watanabe,

2009) suggests that even unconscious visual learning can be effective with visual stimuli showing signs of learning even when subjects were unaware of the stimulus or reward contingencies.

New forms of technology offer a multiplicity of modes for artifact design and creation. Student-generated virtual museums as in our study can serve to unlock the semiotic potential of multimodality in promoting attention to meaning through sounds, music, image, movement and text with a focus on writing and representing (MOE, 2008) as a multi-semiotic resource in conveying meaning in various forms appropriate for the intended audience. Multimodal literacy (Jewitt & Kress, 2003) encourages a range of language-based skills including interpretative skills of content mediated through multimodal forms & representations; evaluative skills in critically assessing the nature, representational techniques, explicit & subtle effects of exhibits; oral and presentation skills in communicating proposed plans and perspectives clearly and effectively; and independent research skills in sourcing and adapting content from multiple sources for specific purposes (D'Acquisto, 2006; Serrell, 1996). Language learning thus becomes concretized from multiple dimensions through the multimodal design (Jewitt, 2006) process. Multimodal communication (Kress, 2003, 2005; Kress & van Leeuwen, 1996, 2001) involving integration of multiple modes of communication within and across different resources now realizes what '*languaging*' means in this New Media Age (Kress, 2003).

3. Research design

3.1. Design research structure

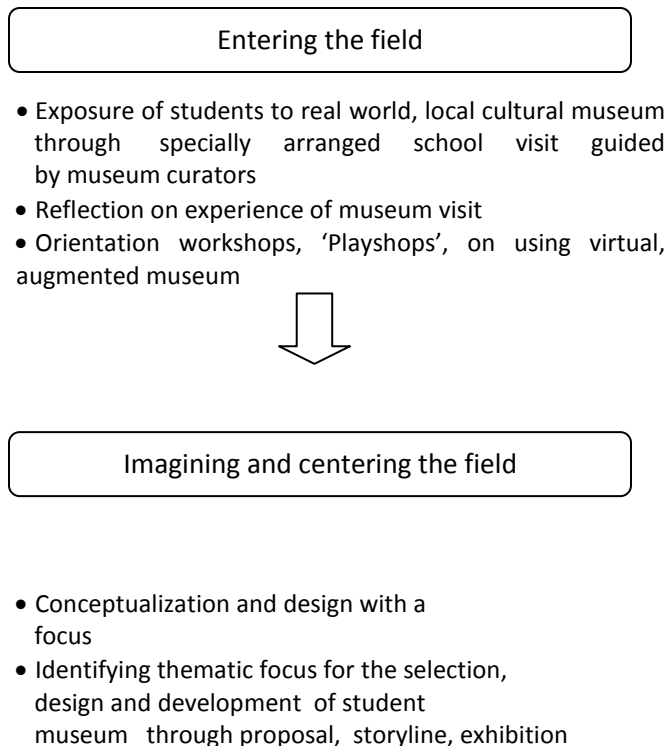
This study as an instantiation of 'design research' (Collins, Joseph & Bielaczyc, 2004) involves 'close collaboration between designers and practitioners' (Bereiter, 2005/2006, p. 17) in investigating the viability of innovative technologically-enhanced, museum-based learning

environments in education contexts. The 'learning by designing' (Di Sessa & Cobb, 2004) focus through an inventive, discovery process is appropriate for this kind of literacy work, particularly as the concept of design is also at the core of multiliteracies pedagogy (New London Group, 1996). Our study reinforced the Singapore Ministry of Education (MOE) 2010 English Language (EL) syllabus focus on multiliteracies to enhance students' 'creative and expressive capacities, as well as shape their personal, cultural and social identity' (MOE 2008, p.8) through 'infusion of authentic, rich texts' (MOE, 2008, p.9) in 'a variety of print and non-print sources to convey meaning' (MOE, 2008, p.58).

The two-cycle intervention integrated into the regular school language curriculum involved students from four English Language (EL) classes. The EL lessons were designed such that students interleaved their use of the technology platform and tools to cycle between active construction, and negotiation cum discussion (Kuhn et al., 2000) with reflective thinking, consistent with Kolb's (1984) framework for experiential learning. Experience is 'relational within a context conceived by the subject' (Clancey, 1997, p. 65) and what is experienced is 'a construction of the person . . . the result of the interaction of the experiencer and the world' (Jenkins, 1974, p.787) which is at the heart of the learning process. Knowledge is created 'through the transformation of experience' (Kolb, 1984, p.41) through the learning process. Students' concrete experience of the actual gallery construction represented a more 'direct, practical experience' (Atherton, 2005, ¶4) in 'the active extension and grounding of ideas and experiences' (Kolb, 1984, p. 52). This alternated with the group discussion and negotiation which supported the 'intensional' (Kolb, 1984, p. 52) mode of conceptual thinking, internal reflective thinking and articulation of perspectives reinforced by interviews with researchers. Underlying an essentially constructivist research framework which parallels other museum

studies (Hein, 1998; Hooper-Greenhill, 1999; Reynolds, Walker & Speight, 2010) is a focus on participants actively engaged in 'constructing' personally meaningful artifacts in the context of a resource-rich environment and becoming collaborative meaning-makers within a specific learning environment. Learning is a process through students' dialoguing in their rounds of discussion and negotiation with each other, self-reflection and through interviews alternating with gallery and artifact construction.

The initial phase involved project planning, scenario and lesson materials development, usability pilot testing and design. The second classroom intervention and data collection phase (Figure 1) comprised several stages – entering, imagining (Lister et al., 2000) and centering, creative construction (Bruner, 1993; Von Glasersfeld, 1987,1995), encircling and deconstructing the field (after critical response modeling cf. Chapman, 1978; Feldman, 1970/1997; Ott, 1989).



script, scale model and presentation based on chosen theme

- Identifying and defining perspective/stance or problem created
- Developing practical line of action as a framework for action
- Ranking in order of importance or priorities: needs, interests, objectives
- Deciding and justifying potential plan/proposal for imagined external audience to attain objectives or meet requirements of situation



Creative construction of the field

- Constructing of background structures, design layout, artifacts, and interpretation.
- Sitting of exhibits within a specific, thematic context and/or cultural perspective drawing on underlying shared assumptions and beliefs
- Planning of museum gallery exhibitions and displays, with consideration given to aspects and factors such as colour, lighting, composition, visitor flow, and other basic elements of design.
- Translating ideas in spoken or written into another medium
- Sourcing, selecting, adapting and creating design layout, artifacts, exhibits



Encircling the field

- Classifying, cataloguing and analyzing products.
- Developing students' skills in identifying, researching, cataloguing, and classifying museum artifacts according to specific, agreed criteria
- Selecting, sorting, sequencing, organizing and classifying information or data related to stance/perspective taken
- Inferring information
- Interpreting simple to moderately complex data accurately and objectively

- Writing descriptive captions for artifacts that integrate image-text relations
- Drawing simply but sound conclusions or generalizations from available evidence



Deconstructing the field

- Reviewing and revising ideas, values and attitudes in the face of evidence or more convincing arguments
- Drawing up identifiable, explicit criteria for assessing quality, impact and educational value of exhibits
- Critical appraisal of the impact of student-generated products/effectiveness or otherwise and evaluating final presentation

Fig. 1. Flow chart of MUSE main intervention phases.

Pre-project, guided real world museum visit provided student exposure to the nature and workings of a museum. An orientation three-session ‘Playshop’ emphasizing creative play and innovative experimentation focused on multimodal meaning-making (Cope & Kalantzis, 2001) and modeling using various stimuli (digital art, sculpture, music, narratives, poetry). Supporting discussions and activities (Kuhn et al., 2000) sensitized students to the nature of multimodal literacies (Jewitt & Kress, 2003). Virtual museum platforms with artifacts were introduced as students learnt to navigate with tools provided. This stage provided the initiation for students to begin imagining, visualizing (Smith & Woody, 2000; Lister et al., 2008) and personalizing their own conceptual understanding of what constitutes a museum.

Through rounds of group discussion and negotiation (Kuhn et al., 2000), students moved into the main construction phase (Appendix A) in the collaborative construction (Jonassen, Peck

& Wilson, 1999; Von Glasersfeld, 1987,1995) of an ‘emergent’ sense of identity (Jewitt, 2008; Lee & Anderson, 2009) representing their collective interests and beliefs. Students classified, categorized and analyzed gallery artifacts. Explicit classroom instruction provided scaffolding on the language to describe artifacts in descriptive captions and in evaluating image/sound-text relations. Students’ oral presentations and walk-throughs of their respective museum galleries at the close of the intervention highlighted the overall purpose, rationale and special features of each gallery. This was followed by peer feedback on the strengths and recommendations for the respective galleries and exhibits.

3.2. *Technologically-enhanced learning platform*

The virtual museum housed the various galleries set up by the student groups. There were 16 different galleries with their artifacts and exhibits in each run. The interactive digital environment provided the background platform in supporting the learning process. In this environment, virtual things (such as text, images, videos, 3D models, animation) were fused with real objects (such as chair, map, guitar). ‘Augmented’ reality (Milgram & Kishino, 1994) ‘enriches’ learning experiences with information graphically added to the real environment perceived. Specific gallery content was dynamically tailored to the learner's environment by displaying images, text, audio input or 3D artifacts in a pop-up window. This study adopted the in-house 3D graphics system developed by the research centre of the university specializing in advanced media technology.

The augmented learning environment was designed in a way that the desktop PC camera allowed different objects into the camera view to project the augmented dimension. These student-generated virtual objects were loaded into the environment following their storyboard. The system also supported audio feedback to be integrated with specific actions. Volume could

be controlled for specific impact (e.g., lowered volume with increasing distance from exhibit). The AR markers used for the galleries were 8.5cm by 7.5cm cards printed on normal paper. The size of each marker could be tailored to students' specific needs as long as the camera could 'recognize' the marker. For example, the 'Local Tourist Attractions in Singapore' gallery showcased tourist attractions such as the Esplanade theatre (Figure 2) with markers placed at locations from a computer screen over a printed, colour Singapore map used as a platform backdrop. With a combination of 3D models and audio voice-over narration activated when the individual zoomed and panned his camera view onto a selected marker, the gallery highlighted the unique attractions of each location.



Fig. 2. Zoom and pan camera view on marker of Esplanade Theatre attraction for audio & virtual information.

4. Methodology

4.1. Study site and subjects

The school identified as a Lead information and communication technology (ICT) school sought to spearhead ICT-mediated pedagogic initiatives in various subjects. The intervention comprising one to one and a half hour weekly sessions of triple EL periods over ten to twelve weeks was held in two computer laboratories with student access to Internet-wired desktop computers.

12 to 13 year old male and female students (seventy eight students in 2009 and eighty students in 2010) were involved. The majority of the students were from a predominantly middle to lower socio-economic background with an average to above average academic ability. Pre-project survey results indicated 84.6% students visited at least one real world museum before the study with 86.7% indicating museum visit enjoyment as they learnt more about local culture and history. 84.6% of students owned a personal computer/laptop/notebook with home Internet access. Students' top three IT-related activities were web-surfing, Internet chat and online gaming. Each class was divided into eight groups of four to five students each to ensure maximum participation and engagement. The teachers (three to eight years teaching experience) in the first cycle were 'IT activists' in the school, tasked with spearheading IT initiatives in EL teaching and learning. Teachers generally had a working knowledge of basic IT use with one expressing personal interest in 'playing around' and 'experimenting' with IT software. All participants were informed of the project and provided signed written consent prior to the implementation. The study adhered to the research ethics guidelines of the university.

4.2. Instrumentation

Data sources included participants' semi-structured interviews, reflections, notes of classroom observation and student-generated products, surveys and questionnaires. Participant

interviews at the pre-, mid and post- intervention stages through focused dialogue yielded useful descriptive data from various perspectives. These face-to-face, thirty to forty five minute sessions were aimed at determining teachers' preparedness, benefits, concerns and recommendations, and students' multimodal perspectives, decision-making rationale, concerns and lessons learnt. Interviews were guided by pre-planned, specific issues for discussion while remaining open-ended to encourage free response. Audio recordings were transcribed and reported verbatim. Open coding was applied to interview data collected to identify recursively emerging issues and major themes pertinent to our research interests.

While the core of the data remained participants' interviews, pre-project surveys provided useful background information on participants' profile. A post-project 20-item student questionnaire (87.5% response rate) reinforced perspectives on the intervention impact in various domains. For this paper, focus centered on specific areas of interest, namely, multimodal preferences and semiotic choices, soft skills acquired, attitudinal and motivational aspects of language learning and aspects of technology use. The response scale comprised items on the following 1-5 Likert type scale: 1-strongly disagree, 5-strongly agree (*SA – Strongly agree, A- Agree, N- neutral, D- Disagree, SD- Strongly disagree). In order to minimize the expectancy effect, students were informed to be honest when answering questions and the confidentiality of their responses. A domain expert panel (Goodwin, 2008) comprising researchers with the expertise to assess and familiarity with our study was consulted over item construction. Items considered ambiguous or complex for the targeted students were revised to ensure the validity of the questionnaire at face value (Goodwin, 2008). A random sample of students was invited to 'test' out the instrument after which statements that posed difficulty for students were revised. The reliability of the items (Alpha Cronbach) for different aspects was >0.7. The subscale scoring were as follows: multimodal preferences and semiotic choices (M -

3.28, SD - 0.41), soft skills (M-3.52, SD - 0.35), attitudinal and motivational aspects of language learning (M-3.43, SD -0. 46) and technology aspects (M-3.75, SD - 0.57).

5. Findings and discussion

We present findings on student-generated multimodal resources and semiotic choices, museum gallery themes adopted before examining the impact of the intervention in various domains.

5.1. Multimodal resources and museum gallery themes

Table 1 provides an overview of the range and type of multimodal products generated and students' semiotic choices from the two interventions.

Table 1

Multimodal resources generated from two runs of intervention

2009				
Multimodal resource	Class A Frequency N=174	Class B Frequency N = 150	Total = 324	%
Text & Image	65	70	135	41.9
Image	73	22	95	29.0
3D Model	24	33	57	17.7
Video	7	9	16	4.90
Text	1	14	15	4.70
Voice Over	0	2	2	0.60
Music	2	0	2	0.60
Image & Music	1	0	1	0.30
Text & Music	1	0	1	0.30
2010				
Multimodal resource	Class C Frequency N = 145	Class D Frequency N = 146	Total= 291	%
Text & Image	36	46	82	28.18
Image	42	31	73	25.09
3D Model	39	29	68	23.36

Text	21	23	44	15.12
Video	7	13	20	6.87
Text & Image & Audio		2	2	0.70
Video & Text		1	1	0.34
3D Model & Audio		1	1	0.34

In both runs, students' semiotic choices indicated an overall preference for still images with accompanying descriptive texts (41.90% and 28.18%), and still images alone (29.00% and 25.09%) - both appearing as the top first or second frequently adopted resource. 3D models including AR-generated artifacts were the next frequently occurring resource (17.70% and 23.36%). These were generated using software based on specific gallery requirements. Students did not appear, however, ready to experiment heavily with a combination of multimodal resources (mix of text, audio, moving images, 3D modeling) given the relatively low frequency (less than 1%). Web-based, video resources featured selective use only for specific media themes (Music, Korean Drama); audio resources (music clips, sound effects) appeared less dominant across galleries. A more selective use of student-recorded voice-over narration, where relevant, was evident as in cuisine information triggered when a menu was flipped open in the Food gallery.

The following illustrated the use of multimodal resources in one gallery. A three-storey Dinosaurs gallery had a roller coaster running on specially designed luminous green tracks to ferry visitors around. Moving closer into the heart of the gallery were lifelike 3D models of four different dinosaurs species and a 3D model exhibition of a cluster of dinosaur eggs. The gallery walls were decorated with different pictorial images depicting dinosaurs' living environment - forested background for land species, deep blue ocean for aquatic species and a sky blue one for

those which can fly. Different wall artifacts presented a mix of text write-ups and images to provide more in-depth information about the dinosaurs.

The quantity of multimodal resources generated raises the issue of selective choice of relevant, quality resources for intended purposes. Similar to studies (Vavoula et al., 2009) where initial random resource collection often exceeded instructor’s recommendation, monitoring of students’ artifact repository with adequate time provision for students to ‘meaningfully process’ and ‘critically examine’ (Vavoula et al., 2009, p. 12) artifact value and potential for their proposed galleries would be beneficial. The need for selective, informed choices in artifact sourcing and creating is critical for effective multimodal meaning-making.

Gallery themes (Table 2) revolved predominantly around national, topical interests (Youth Olympic Games 2010 which Singapore hosted), popular aspects of youth interests (music, toys, movies and television drama series, comics, gaming, dinosaurs), school life, the local Singapore context (humor, religion, tourist attractions) and other issues from paranormal happenings, gender superiority to geographical topics on a global level (Natural disasters, Seven wonders of the world).

Table2
Overview of Museum Gallery Themes

Category	Class/Year:		2009		2010		%
	A	B	C	D			
Youth Interests (for older group)	Online	Music	Gaming	Movies			25 (8 groups)
	Computer Games		Music	Movies			
	Korean Dramas		Japanese Manga				

Youth Olympic Games (YOG)	Youth Olympic Games	Youth Olympic Games	Youth Olympic Games	Youth Olympic Games 2010 Youth Olympic Games 2010	16 (5 groups)
Youth Interests (for younger group)	Toys Zoo Animals	Looney Toons	Dinosaurs		13 (4 groups)
Health & Sports	Healthy Living	Food	The Extreme Stuff		9 (3 groups)
Singapore Interests	Singapore Humor	Tourist Attractions in Singapore Religions in Singapore			9 (3 groups)
Geographical on global scale				Seven Wonders of the World Natural Disasters	6.25 (2 groups)
Specific Interests: Supernatural or Paranormal Themes			Haunted House	Paranormal Happenings	6.25 (2 groups)
School Life: Nan Hua High School		Nan Hua School Life	Nan Hua School Life		6.25 (2 groups)

Dance	Dance	Dance	6.25 (2 groups)
Gender issues	The Pink Future		3 (1 group)

Of the 32 groups, 25% chose Popular Youth Interests/Hobbies themes such as computer gaming, music, movies and media related entertainment. 16% focused on the topical Youth Olympic Games 2010. Early adolescent interests - cartoons, toys, animals and dinosaurs - comprised 13%. 9% were local-based themes on Singapore humor, tourist attractions and religions with a further 9% for Health & Sports. Themes of school life, dance, the supernatural and geographical interests and natural disasters stood at 6.25%. 3% were related to gender issues. Thematic choices generally indicated strong associations with youth sense of self and culture with a few extending beyond their personal spheres to global interests on a wider level.

5.2. *Intervention impact in specific domains*

At a macro level, participants' feedback demonstrated the impact of the design intervention in specific domains. Identifiable thematic areas which emerged comprised participants' multimodal awareness, collaborative learning, language learning perspectives, curricular issues and aspects of technology use. We present qualitative descriptive data with illustrative extracts (T-Teacher, S-Student, R-Student Reflections) supported by classroom observation and quantitative input, where relevant, to reinforce our observations of the impact of the study.

5.2.1. *Participants' awareness of multimodal impact and semiotic affordances*

Multimodal awareness in our study, drawing on van Lier's (1995, p.3-4) 'focal awareness', refers to understanding and attentive consciousness to 'the ways individual semiotic modes and modes in combination may be drawn upon in the designing of meaning' (Nelson, 2008, p. 70). Teachers' positive gains for themselves included a heightened awareness of the value of multimodal stimuli:

T2: I get to experiment with these various sorts of stimuli and non-print resources which I see as helpful in my language teaching for my students to go beyond merely written 'texts' and print' to make meaning.

This evidently was also observed in their students:

T1: Begin to appreciate how language can change.. help students in writing because instead of merely just trying to visualize, they have the chance to see the characters' purpose.. using different senses to appreciate the language.

T3: More sensitive towards such medias, images and even the language and colors.

So I guess subconsciously, at the very least, they realize that learning is not just about the text, and production of English isn't just about using words.

Students themselves reported a growing awareness of the impact of multimodal forms of expression:

S1: Besides being more attractive and vibrant, a picture allows more creativity since a picture can speak a thousand words. For example, figures of gods and statues can be expressed easily in pictures. Sound effects were used to present the atmosphere and the setting of the surroundings like the process of the Muslims praying in the mosque where there would be some singing and chanting.

with emergent signs of their sensitivity to the targeted use of semiotic resources for specific purposes and contexts:

S15: The choice of a picture was because it came along with the textual write up so it helped to reinforce the description within the text. For the picture itself, the main color that could be seen was Red and symbolically within the Chinese culture, Red tended to represent Happiness and Joy. The dancers were moving their scarves in a very graceful manner, up and down, it is like very light, just like floating in the sky.

Visuals and color were recognized to play a significant role representing visual arts of movement. This is gaining interest in the field with a focus on examining ways whereby visuals (Jewitt, 2008a; Kress & van Leeuwen, 2006) communicate meaning, resulting in structures or a 'grammar' of visual design (Kress & van Leeuwen, 2006) of their own. In another case, text was perceived to have a specific value of its own. In answer to a question 'What are words good at?', the following highlighted the 'profound' quality in picture descriptive text:

S15: Text further describe a picture using like more profound words.

S14: *Cheem* (Hokkien dialect) words.

S15: It is like a word to describe profound.

S14: Like the vocabulary too powerful for someone to understand this.

Text was also perceived to play a supportive role in enhancing the use of visuals:

S8: because some things cannot be seen from the picture so words can also like tell them what the picture talks about.

Image-meaning was enhanced by textual content with this 'multiplying meaning' (Lemke, 1998a) effect, consistent with New Literacies (Barton et al., 2007, Gee, 2008, Street, 2008) integration of written, visual, audio modalities. Students also appeared to recognize the stimulation of multiple perspectives of things:

S11: People have different opinions. People have different ways to view a photo, when they view it; they have different opinions about it. Then pictures have more points than text can explain.

R24: Hard to find one way to say all. Sometimes words tell information better. Other times, image has different angles for different people, way we look at things not the same for everyone. No one way to see things.

in addition to activating the multi-sensory dimension:

S7: You can view it, you can view the dance, you can see and you can touch.

R13: it makes me wake up to language through seeing, hearing, doing, feeling.

These reinforced prevailing interest in shifting the view of literacy away from a mono-modal phenomenon to a multisensory perception and experiential dimension where modalities of

meaning (Jewitt & Kress, 2003; Kress, 2000; Kress & van Leeuwen, 2006) were enhanced through varied dimensions and layers of sense- and meaning-making. Our classroom observations supported this as we noted students drawing and re-drawing in pens and pencils on and against each other's design layouts and gallery plans in their earnest attempts to sketch the mapping out of the galleries structural designs. Pens in various colours were used to shade, outline, even delete earlier sketches of artifacts and exhibits to concretize their diagrammatic plans. Attention was given to sketching spatial details and material specifics with regard to particular facilities and resources (car park with sufficient lots, toilets around strategic areas, drinks and snacks vending machine, cafes) proposed for their galleries. These supported our hypothesis that MUSE provided opportunities for students to be sensitized and to concretize various aspects of multimodal stimuli - spatial, size, positioning, colour, object details – which would not have been otherwise evident through working on a purely text written product. These paralleled findings from other studies (Kress et al., 2005; Stein, 2007) on multimodal perspectives on teaching and learning.

Sporadic instances of an emergent awareness of semiotic limitations or constraints were evident as with text limitation:

S9: We think that the essay is very boring

S13: They cannot really know a lot from the essay, like *cannot sense*.

We see the potential in building on this budding awareness of students to recognize and understand material constraints for representation and communication (Jewitt, 2008b), particularly with design creativity acknowledged to be 'quite often the result of overcoming constraints rather than of formal innovation' (Bouissac, 1998).

Overall, students' bald, relatively simple comments remained on a surface level in acknowledging the nature and value of multimodal resources without delving deeper into engagement and interactivity specifics across multiple resource types. These were reinforced by sample questionnaire responses on students' perceived multimodal appreciation:

Table 3

Participants' responses to multimodal aspects of meaning-making and design

Statement	SA	A	N	D	SD
By now, I have a relatively good idea of what Multi-Modal meaning-making means.	44.28	47.14	4.29	4.29	0
Colors play an important part in expressing what I want in my museum.	21.43	68.57	10	0	0
My gallery layout/physical design has an important role in expressing what I want about my museum theme.	34.29	55.71	5.71	1.43	2.86

Emergent signs of students' growing awareness and sensitivity to the impact and value of multimodal resources were evident although there were, admittedly, not widely nor consistently evident across all participants. There is room for more work in broadening students' perspectives on semiotic affordances (Norman, 1988) and constraints, and in manipulating semiotic resources across various modalities for targeted effects. The findings reinforced studies on awareness of semiotic affordances (Hull, 2003; Walsh, 2007) with initial, nascent signs of adolescents' understanding developing in this area. Presently, work is under way at this time in unpacking representation of students' identity and voice through the multimodal constructs generated.

5.2.2. *Virtual and augmented reality and multimodal meaning-making*

The technology provided students as design-makers of their museum galleries the opportunity to reshape (form of the) resources in relation to their interests and needs. This approximated 'transduction' (Kress, 2003, p. 47) – 'a process in which something which has

been configured or shaped in one or more modes is reconfigured, reshaped according to the affordances of a quite different mode'. Gallery-artifact examination showed how the Food gallery students working on a local cuisines menu presented 'knowledge' in the (mix of) modes of image, sound - visuals of cuisine with voice-over narration and ethnic group background music - which was re-presented in another mode through the cuisine 3D, augmented model triggered on feeding the menu marker over a web camera. Augmented content enabled knowledge which was 'configured through the affordances of the various modes' to be '*drawn across*' (Kress, 2003, p.47) into another mode. It was in this realm of translation of 'shifts of semiotic material' (Kress, 2003, p. 36) across modes that much of what was perceived and regarded as 'creativity' happened. While there were visible attempts of some students capitalizing on this form of the technology for targeted purposes, we did not, however, see this experimentation with multimodal resource shifts dominate all galleries. The galleries capitalized generally on unilinear, still images with and without texts (section 5.1). At best, our study enabled students, if they so desired, to privilege specific perspectives from various angles and dimensions but more needed to be done. Students' technologically-mediated multimodal choices could reflect how particular choices constructed alternative viewpoints and broadened the scope and layers of meaning-making in a dynamic way. This would be aligned with the EL syllabus interest in multimodal texts providing a platform to enrich students' language learning while expanding their repertoire of interpretive and expressive skills. In line with the prevailing thrust of New literacies, this reinforced the 'multiplying meaning' (Lemke, 1998, 2002) effect whereby 'meanings made with each functional resource in each semiotic modality can modulate meanings of each kind in each other semiotic modality', thus 'multiplying the set of possible meanings made' (Lemke, 1998, p. 92). The attempt was towards raising awareness that meanings encoded in various multimodal resources 'may semantically converge in multiplicative ways' (Nelson,

2008, p.66). There was the added challenge of working towards the ‘unification or amalgamation of elements of meaning’ (Nelson, 2008, p. 68) through a purposeful semiotic integration of the various resources.

5.2.3. Group work and collaborative learning

Teachers reported gains in interpersonal student awareness through group work:

T2: Definitely they got to work with people they don’t normally associate themselves with within the group because I assigned them. And how the different groups actually worked, you know, it made things a lot easier when I had other group projects for them.

and students benefiting from adult interaction with the academic researchers and computing staff:

T1: they learn teamwork as well as with the lecturers like NTU staff because I don’t think that they interact much with adults.

Positive benefits of group work over a sustained period ranged from teamwork and collaboration were reported by students:

S: An advantage is that since every individual within the team has their own ideas, we can put all these ideas together to form even better ideas to enhance our gallery.

S: I think that I will prefer working as a team better than alone. When we work as a team, we can build up teamwork through the division of the workload. We have, since we have more members to brainstorm, we can think of more creative ideas for our gallery.

in addition to learning more of their peers:

R7: We learn who is strong in what areas. He helps to do more in that area. Who is not so strong in one way, he can do other things.

R9: This is a form of learning. How well we actually understand each other. sort of like now we know each others’ feelings, likes, and our museum will be like, it is like all of us like the museum that kind.

and emotional support:

S18: MUSE helps to further bond some of our classmates together because we started when we don’t really know and like each other. Now we can help each other. When one down, we try to support him, care for each other.

In the classroom, we observed high levels of group talk and participation on the tasks set. Working together encouraged the students to discuss, provide input, explain, ask questions, challenge each other in order to find solutions to solve the problem (Kuhn et al., 2000). Students' engagement in group discussion broadened their perspectives as they learnt to look at things from different angles, and led to revision and refining of original ideas. Questionnaire findings and reflections reinforced perceived benefits from group work and collaborative learning:

Table 4
Participants' responses towards collaborative learning

Statement	SA	A	N	D	SD
Given another similar project, I would prefer to work in a group.	51.85	37.14	5.29	4.29	1.43
Group work for this project has more advantages than disadvantages compared to individual work.	47.14	44.29	7.14	1.43	0
From this project, I picked up one or more skills useful for working as a team.	25.57	64.29	4.29	2.86	2.99

R2: I don't think I would enjoy the work so much if I do it on my own. I also learn more about my friends which I did not know earlier.

R14: We have fights when we don't agree. We try to work with each other. It is hard but we learn. We grow together.

The collaborative learning (Kuhn et al., 2000; Vygotsky, 1978) dimension was unpacked from two angles: students learning on their own, and students learning with others in the group (Looi et al., 2010). The descriptive results indicated students' agreement that there were gains from working in groups as compared to working alone and that they acquired skills as in learning to negotiate and make decisions from collaborative learning. These findings suggested overall positive gains that paralleled technologically-enhanced intervention studies which facilitated collaborative learning well (Looi et al., 2010) through student engagement in group work with

more student 'ownership and responsibility for their own learning' (Looi et al, 2010, p.24) and for their peers.

5.2.4. Language learning perspectives and attitudinal, motivational aspects

Participants' attitudinal and motivational aspects towards language learning, affective and specific language gains and perceptions of multimodal meaning-making were observed. Noticeable students' attitudinal and motivational changes to EL lessons were reported by teachers:

T1: They are a lot more responsive and enthusiastic about the project.

T2: I guess to an extent they were keener on language learning.

with opportunities for developing creativity:

T3: They are allowed to imagine and think out the box and that helps a lot.

T1: They think more creatively and look at things from a different perspective and I think that helps.

These findings were reinforced by students' feedback on affective effects and creative stimulation:

S5: Our class language work is different, more worksheet writing, not so fun. I like EL lessons from this project. We work with language in pictures, sound, models to make our ideas, thoughts come out in strong ways. Enjoy.

R6: Makes the lessons feel more interesting. Yes because it develop our creativity skills. This is like a new age thing.

S14: You can like use your own imagination because it is like our own museum right. You can add in your sense of creativity.

Specific language gains were cited in terms of reading and summary writing skills:

S22: At first we didn't want the text to be too wordy so we need to know how to summarize and then after this project, we learned how to like sort of summarize the summary of all the information and reports. Then break it into parts. To put in the museum.

and oral presentation skills:

R20: Help us to express to better. There is more confidence to speak out loud like just now, we learned to present our presentation, why we did this, why we did that, etc.

in addition to confidence building in persuasive skills:

S19: So it is like a bit.. so they will like broaden their knowledge from the descriptions so they will be like if you want me to tell my friend, I would say like that it will make you more creative and more confident of your ideas because you need to have lots and lots of evidence and thoughts and points to prove and argue that okay this point is good.

Multimodal design was also viewed as a strategic means to capture attention:

S18: You can like exhibit the stuff as and where you like. You can learn how to like capture the viewers' attention and all that. To make a point. To argue.

This directed focus towards the targeted impact and value of the multimodal product sets the ground for developing attention to foregrounding pertinent aspects in design specifics and criteria (Levy & Kimber, 2009) for intended purposes.

Sample questionnaire responses reinforced findings on writing skills enhancement and creativity:

Table 5

Participants' responses towards language (writing) skills and creativity

Statement	SA	A	N	D	SD
I feel that the project and its writing tasks have helped me to improve my writing abilities.	52.92	35.71	4.23	5.71	1.43
I enjoyed working on this project as it allowed me to be creative and to look at things from different perspectives.	19.75	66.48	3.29	3.68	6.80

In the classroom, we observed students' heightened energy levels each time we saw them for their EL lessons. The animated, lively discussions, laughter and verbal chatter characterized the nature of many of these sessions which saw them earnestly dialoguing while on on-task and over which the teachers found themselves having to exert firm discipline to gain their attention. The interviews, reflections, questionnaires and our observations rendered support to our findings

with regard to the generally overall positive perspectives of language learning in a novel way, similar to studies in reporting novice subjects' responses to technologically-enhanced, active learning (Barak, 2006,2007; Dori & Belcher, 2007; Looi et. al, 2010) in new environments which offered a 'unique learning experience which actively engages users in investigating new concepts' (Barak et al., 2009, p. 849).

5.2.5. Curricular-technology integration and pedagogic skills transfer

The intervention was targeted for integration into the regular EL curriculum with alignment, as far as possible, with curricular goals and departmental schemes of work. Careful planning, tighter monitoring and strict control with a more focused, strategic management and execution of project tasks were required to maximize the limited in-class, curriculum time available and to ensure the effective transfer of language-based skills required from the regular curriculum into the contextualized project writing tasks.

Initial critical gaps in expectations between key project personnel, namely, computing specialists and language academic researchers, to fully understand technological capacity and operationalization within real world classroom constraints posed a challenge. Making informed decisions as to the appropriate platform and tools for students' work while fulfilling curricular requirements had to be addressed. A delicate balance between not having the technology override the curriculum but ensuring curricular objectives on multimodal engagement were reinforced through the technological mediation was targeted through discussion and negotiation.

Regular, closer monitoring sustained over the construction phase supported by the availability of just-in-time help from key resource computing specialists 'adopting' assigned student groups to work with reinforced by explicit written instructions and procedures, graphic

organizers for planning, and availability of students' hard copies of floor plans and design layouts to facilitate revision were critical.

Professional development of teachers in design research enculturation (Chen, Looi & Chen, 2009) to develop a fuller appreciation for school-based interventions, and to acquire the appropriate mindset and required skills would enhance the effectiveness of projects of this nature. Further, practitioners' understanding of the newly implemented language syllabus demands and requirements, and in integrating project goals and curricular objectives cannot be overlooked.

5.2.6. Design and usability issues in the technology adopted

Initial technical difficulties pertained to portal and material access and retrievability resulting in curriculum time wastage during the active construction phase. More user-friendly, freely accessible 3D modeling software for students' independent use was adopted in the second run based on novice students' initial difficulties. Software for efficient data conversion and transfer of student-generated graphic intensive, digitally-mediated data was subsequently introduced to address data transfer complexities. Instructional procedures scripted by computing specialists in simple, easy-to-understand language on software use (Google Sketchpad, Audacity) by students were necessary. Explicit modeling with exemplar tools and software used, as in sample scripting and in-class voice recording, were critical in the demonstration phase.

Teachers' initial concerns centered around classroom logistics, lesson execution issues in terms of structure and organization, and their own level of preparedness for design research and technical design software competency. These were later addressed with the necessary supportive technical input, logistical adjustments, lesson flow and structure modification (Appendix A) to accommodate unanticipated complexities which echoed studies (Vavoula et al., 2009) that

reinforced the need for ‘continuous evaluation and fine-tuning of the new technology with the learning practice’ (p.298).

Despite the initial technical, logistic difficulties, an overall positive response was registered with regard to technology adopted as reflected in questionnaires on perceived advantages in the operative (ease of use) and functional (ease of ideas expression) aspects of the technology:

Table 6
Participants’ response towards technology use

Statement	SA	A	N	D	SD
The various technology tools, resources, platform that I learned during the project were relatively easy to use.	20	65	12.14	2.86	0
By using Augmented Reality (AR) technology (putting computer-stimulated artifacts on real objects), I can express my ideas easily and more clearly.	23.43	64.29	5.71	5.14	1.43

These resonated with studies which reported generally positive operative use and attitudes over the earlier capacity of technological platforms and systems developed (Barak et al., 2009; Beazley, 2007) and modified over time.

MUSE system goal focused on developing an application prototype for students’ hands-on discovery learning through collaborative design and construct of multimodal artifacts and exhibits for a virtual museum. The virtual, augmented learning environment stimulated students’ curiosity and interest by actively promoting multimodal engagement throughout the design process. A key impact targeted was student exposure to a range of semiotic resources, multimodal awareness and sensitivity to semiotic affordances and constraints, aligned with New Literacies (Barton et al., 2007; Gee, 2008) focal interests and emphases. Our study indicated

students' choice of multimodal resources was limited to predominantly still images and some adoption of 3D models including AR-generated artifacts. We believe that focused, sustained multimodal exposure would broaden students' use of multimodal resources, even positively influencing them to innovatively experiment more with manipulating and integrating an appropriate mix of multimodal resources for specific purposes. The multimodal products offered concrete manifestations of students' 'sign making' (Jewitt, 2008b, p.253) which were valuable in providing the basis for critical engagement, interpretation and resources for teaching meaning-making in various genres. The move from viewing semiotic resources as discrete units to making meaning through establishing purposeful interactive links across various resources (Duncan, 2004; Luke, 2003) required further work. The challenge was for students to work towards a meaningful synthesis, that is, shifting 'from collection to connection' (Luke, 2003, p.400) to establishing links and coherent flows across varied multimodal resources.

Research literature has shown that active learning occurs through collaborative knowledge construction and social interaction (Bruner, 1993; Stahl & Hesse, 2006) in technologically-mediated learning environments. In this respect, one of MUSE aims was to provide an innovative learning experience which actively engaged participants in collaborative exploration and discovery of multimodal resources, adapting and modifying appropriate materials for specific purposes, designing gallery floor plans and layout and constructing descriptive captions for artifacts and exhibits. Our participants revealed generally positive gains through the digitally-mediated learning experience in terms of attitudinal and motivational aspects of language learning, broadened their perspectives of multimodal communication and benefitted from collaborative learning skills. Students valued the creative resourcefulness and imaginative, inventive thinking required, arising from designing their own exhibit

representations. This paralleled museum-based studies (Vavoula et al., 2009) with student appreciation of the value of this aspect of the inventive work.

MUSE system and technological capacity was developed primarily in this study for novice participants largely unfamiliar with technologically-enhanced, museum-based platforms. Despite the initial technical, logistical difficulties, design and usability issues were addressed with the timely refining of peripheral and contextual support. This included tightening up procedural processes with closer monitoring, improved design and data transfer software. This reinforced intervention studies (Ho, Rappa & Chee, 2009; Vavoula et al., 2009) where operative and systemic issues necessitated on-going, follow-up support during implementation. Mediating learning through virtual, augmented content, while stimulating multiplicity of perspectives through multisensory learning in bridging the virtual and the real, remained an endeavor still in its infancy. Future work in maximizing the potential of augmented learning as evidenced in studies (Mueller-Wittig, Zhu & Voss, 2007; Song, Elias, Mueller-Wittig & Chan, 2004, 2005) could emphasize greater dialogic interaction, enhanced participant and artifact engagement. We postulate further opportunities for developing the socio-technical design through building upon our prototype platform to enhance multimodal capacity, and raise interactivity and engagement levels. One specific enhancement would be to develop a facility inherent in the system for direct, immediate text uploading to accompany digital content in augmenting artifact displays. The feature could be enhanced to facilitate visitor input of feedback text comments on artifacts viewed. This would reinforce research in the field on enhancing interactivity and engagement in museum-based contexts (Ho, in press; Jewitt, 2010).

6. Conclusion

Our paper drew on an empirical study that involved the design, implementation and evaluation of a technologically-enhanced, museum-based, design research within the context of a language curriculum. *MUSE* sought to enhance students' multimodal awareness, stimulate imagination and creativity as young designers of meaning in 'student-centred, student-directed, collaborative' (Karagiorgi & Symeou, 2005, p. 19) constructivist learning contexts. The aim of this paper is to examine the design and implementation process, and study the impact of the intervention in specific domains. Indeed, as Jewitt (2006, p. 158) reminds us, 'new technologies introduce new resources for representation, new sites of display, new forms of engagement, new practices for students and new potentials for interactivity'. Along with this is the challenge for 'a re-thinking of learning and literacy' (Jewitt, 2006, p. 160) with classroom practitioners and students as 'the designer(s) of context' (Jewitt, 2006, p.160) and technology merely as a resource.

Reinforcing technologically-mediated studies which encourage collaborative knowledge construction and active learning (Barak et al., 2009, Dori & Belcher, 2005), this project reported emergent signs of students' growing awareness and sensitivity to the value and impact of semiotic resources although these were not widely nor consistently evident across every single participant. There was room for greater exploration in the integrated use of a wider range and purposeful combination of these resources for digitally-mediated meaning-making beyond the present limited confines to predominantly still images, 3D models.

The study indicated the viability, to a certain extent, of the intervention within a classroom context to fulfill targeted curricular goals. There is potential for the AR technologies developed in the virtual environment to be customized to the requirements of research projects at relatively low cost (compared to developing a similar learning environment from scratch). Minor usability problems did not appear to have detracted very much from students' learning

experience. Issues concerning structuring the specific museum-based learning experience, and the scalability or localization and contextualization of *MUSE* as a regular service to other potential school users will have to be addressed in future. It was intended that the application prototype developed would lead to further adaptation for contextualized use in other learning contexts.

We acknowledge that this study, at this point in time, was essentially limited to intervention within a regular school curriculum that involved a specific, relatively small community of learners and teachers in the experimental classes involved. We believe, however, that the study has demonstrated the potential of carefully designed research interventions to meet specific pedagogic objectives. Studies of this nature can contribute to a deeper understanding and fuller appreciation of projects which seek to enhance students' multimodal awareness and engagement with varied semiotic resources over a focused and sustained period of curriculum time. Systemic, curricular and pedagogical support integrated to meet practitioners' needs and fulfill curricular goals must be taken into account. The challenge for designers, researchers and practitioners is to contextualize appropriate technological requirements, design specifics and structural demands while taking into account the characteristics of particular instructional environments with specific curricular emphases and communities of learners even before scaling up the digitally-mediated learning tools and resources for implementation in other educational contexts. There is room for future research in a wider range of contexts at various levels as in elementary and post-secondary, and in other disciplines such as Humanities, Science in order to build comprehensive understanding of the full potential and impact of student-generated virtual, augmented museum tools and resources on learning in different instructional settings.

Appendix A. Extract from main intervention schedule

Computer Lab Session	Learning Objectives	Curriculum Materials / Resources / References	Activity
Week 1 Pre Report on Gallery Proposal Resource Collection	Confirm theme/topic for museum gallery Gather and compile relevant resources	<u>Students' Resources:</u> Handouts on Group Think Sheet, Youth resources ref list (given in Jan 10), Report on Gallery Proposal task sheet	S confirm on their choice of theme/topic. T offers input on resources/ref list. S confirm museum floor plan/layout. S upload resources collection into the MUSE portal according to their modes (3D, images, videos, text or audio). T inform S by Week 2 to submit typed report on Gallery Proposal/ carry out a mini presentation on contents of proposal.
Week 2 Report on Gallery Proposal Presentation Resource Collection	Present group report on Gallery Proposal Elicit peer feedback and T for revision Gather and compile relevant resources	<u>Students' Resources:</u> Completed report on Gallery Proposal	S present group report on Gallery Proposal/ upload on MUSE portal. S & T offer feedback. S upload resources collection into the MUSE portal according to their modes (3D, images, videos, text or audio). S Interview Round 1 (Pre Project Phase)
Week 3 Resource Collection	Gather and compile relevant resources Reflect on individual creation and process	<u>Students' Resources:</u> Reflection Task Sheet (Week 3)	S upload resources collection into the MUSE portal according to their modes (3D, images, videos, text or audio). S complete Reflection Task Sheet (Week 3)
Week 4 Resource Collection	Gather and compile relevant resources		Deadline for S to upload resources collection into the MUSE portal according to their modes (3D, images, videos, text or audio).
Week 5 Construction phase Total 1hr	Modeling/Construction work where relevant		T notes the real objects that S brought and planned to display within their museums. T monitors S construction of multi-modal features chosen for their galleries and gives advice where necessary. Modeling/construction work with guidance from NTU staff. (Artifacts, e.g. 3D models, animation, etc requiring more time/work to be identified and directed to NTU staff asap after lesson)
Week 6 Construction phase	Modeling/ Construction work where relevant To reflect on individual creation and process	<u>Teachers' Resources:</u> Caption Label samples <u>Students' Resources:</u> Caption Label Task Sheet	S complete Caption Label Task Sheet. T monitors S construction of multi-modal features chosen for their galleries and gives advice where necessary. Modeling/construction work with guidance from NTU staff

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Figure captions

Figure 1 Flow chart of MUSE main intervention phases

Figure 2 Zoom and pan camera view on marker of Esplanade Theatre attraction for audio & virtual information