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Immersive Learning

From Basic Design for Communication Design: A Theoretical Framework

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In this paper we discuss the two changes that basic design education faced: one is the teaching need of transformation from visual to multisensory and synaesthetic communication; the other is the use of virtual environments to teach design. As an answer to the trend of constructivist learning, also in order to fulfil the need for multisensory training, the discussion of an innovative learning environment for basic design education has become essential. The problems remain, as virtual technology has limitations regarding visualizing abstract concepts. This research aims to build an immersive virtual environment to teach basic design, along with the value of subjective immersive experience for design learning in general. The study presented in this paper proposes a theoretical framework, starting with the redefinition of the concepts of "immersion" and "presence" from a cognitive perspective (Scuri, 2017). The main research method is based on two groups of case studies; through literature review and secondary research, this work categorizes the factors of presence into a three-dimensional framework, also defining the four typologies of immersion and two in-class educational models. The paper presents the results of the research at the first phase, aimed at bridging the gap between design learning and virtual spaces. Through the framework addressed, we are able to frame an actual design tool with the help of online platforms and tools.

Keywords: Immersive learning; Innovative teaching; Basic design; Synaesthesia; Virtual learning environment;

Introduction: The Transformation of Basic Design

The relationship between design education and virtual technology could develop a new integrated system. Design education has always been recognized, and is still always recognized, as highly creative and participatory. The benefits of virtual technology, with immersive simulations and flexibility of virtual dialogue, remain some of the key benefits for interactive and/or by remote didactic. In the twenty-first century, more sensory-involved technologies needed to be addressed by designers who are better equipped, leading to innovation in educational tools and methods.

Basic design, usually referring to the training of abstract design fundamentals (Neves & Duarte, 2015), is both the starting point and the main research objective, not only as it is a fundamental means to teach design capability, but also since it deals with abstract design principles, which leads to broader teaching and learning discussion based on cognitive immersion.

In this section, we discuss the two changes that basic design education faced: one is the teaching need of transformation from visual to multisensory and synaesthetic communication; the other is the use of virtual environments to teach design. Therefore, we are able to hypothesize the concept of immersion (usually provided by virtual learning environments) as an innovative teaching method for design.

The Transformation from Visual to Synaesthetic Communication

Multisensory learning methods, which usually engage the coordination between visual, auditory, kinesthetic, and tactile inputs, appear to achieve a better teaching effect (Chandrasekaran, 2017; Shams & Seitz, 2008). The importance of multisensory integration, which appears both on the expression and cognitive recognition,

meets the educational needs of designers and leads to more comprehensive design products (Chandrasekaran, 2017). The significance of multisensory input is not only that it better develops students' sensory abilities, but also that it allows one to obtain a logical path of synaesthetic translation (Riccò, 2016).
Basic design has made attempts to innovate within-discipline learning, and is constantly innovating its education model. In this context, applying a synaesthetic approach - that is, considering the interactions and links between information from different sensory registers - can be of support to train students not only in visual observation, but in induced perceptual changes from sensations of other modalities.
At the Politecnico di Milano, synaesthetic workshops for visual, audible and taste are studied as components for basic design learning (Anceschi & Riccò, 2000; Riccò, Belluscio & Guerini, 2003; Liu, Calabi & Riccò, 2018). The urgent needs for multisensory and synaesthetic training in design opens the door for the engagement of virtual technology, which involves various amounts of sensory stimuli and the ability of scene simulation. Possible sensory interactions (especially within an virtual environment) seems to be the enter point for innovating design learning, such as engage multiple sensory within an comprehensive environment, to expand the contents and forms of traditional learning activities. The examples can be various, among the recent experiences conducted in basic design in the Italian context, of particular interest the interactive basic design by Cristina Chiappini[1] and the basic design procedures by Lorenzo Bravi[2] which apply programming languages.

Virtual Technologies in Design Learning

As stated above, it is not novel to consider design learning with virtual and digital technology, yet previous efforts should not be ignored. A relevant number of studies understand virtual technology as the new teaching and learning tool for design (Neves & Duarte, 2015; Neves et al., 2016; Calabi, Mottura, Sacco & Vigano', 2003; Liu, 2020). In 2016, Neves and Duarte used VR-based tools to enhance the effectiveness of basic design learning. Students studied and tested basic design topics, demonstrating that virtual tools were effective both for the discussion of the exercise and for exploring abstract structures (Neves, Duarte, Dias & Saraiva, 2017).
In juxtaposition to the common cognition, virtual technology can be effective in both graphic and interior design, rather than being limited to disciplines with high three-dimensional demand such as architecture and product design. Dalgarno and Lee's (2010) research addresses a wide range of learning effectiveness to promote spatial knowledge representation, including experiential learning, contextual learning and collaborative learning. The sense of presence provided by immersive VR assists with spatial visualization to enhance learning outcomes. The simulation of scenes or spatial environments could also be beneficial for problem-based learning, as it could immerse the students in a real design problem. It matters little whether the design problem is concrete or abstract; what remains important is to incorporate the principles under the creative process (Neves, Duarte, Dias & Saraiva, 2017).
It makes sense to discuss basic design education within an VR-based environment, as those technologies have potential to benefit the learning activity by engaging students in perceptual actions and concrete approaches towards abstract objects. New ways of in-class interaction are available, and students may explore design disciplines in a highly interactive and immersive environment. The virtual learning environment (VLE) shows great potential for virtual simulations within architecture and medicine, as well as great potential in art exhibitions. Compared with web-based learning, the possibility of virtual interactivity and a deeper feeling of presence is fundamental when it comes to virtual dialogue.
To sum up, the benefits of teaching basic design with virtual technology include:

- promoting the understanding of abstract knowledge, which remains essential for teaching design principles;
- enhancing the learning outcome by further involving the students thanks to the feeling of presence implicit in VR technology;
- compatibility with innovative teaching methods;
- promoting virtual environments both for in-class interactions and social dialogue.

Immersion as a Subjective Mental Description for Design Learning

It is fundamental to discuss the concept of immersion as the starting point of this research. In 1997, Slater and Wilbur defined the term immersion as "the extent to which the actual system delivers a surrounding

[1] See: https://cristinachiappini.com/category/interactive-basic-design/.

[2] See: https://www.lorenzobravi.com/ftp/basic-iuav/IUAV-reference.pdf.

environment, one which shuts out sensations from the real world”. Witmer and Singer later (1998) raise objections to immersion identified as an objective description of VE technology. In short, other factors such as attention, focus, involvement, and engrossment may affect the level of presence from a subjective level. They argue immersion as a “a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences”. The engagement of immersion (usually through VR tools) has opened a new path for design didactic rather than the old way of learning (de Freitas et al., 2009), yet further efforts should be put into the identification specifically under the subjective perspective.

For design learning, the concept of immersion can be understood from two perspectives. One is to understand immersion as a subjective mental description (Scuri, 2015). Physical immersion is achievable through the characteristics of virtual reality, while mental immersion is a main task of communicative media. The other is from the educational perspective, to understand immersion as an innovative teaching method, that has already been discussed through the studies of medical treatment, military and safety training. Its main approach is not limited to the simulation of a real scene and virtual narrative; instead, it compliments new teaching methods, including experimental learning (De Freitas & Neumann, 2009; Beckem, 2012), conceptual thinking, and multi-perspective information transformation (Scoresby & Shelton, 2011). New educational methods and tools make efforts to consider a multisensory environment rather than individual sensory channels like visual or audible (Haverkamp, 2012).

Therefore, to define the concept of Immersion and Perception for design (Calabi, Chiodo & Scuri, 2015) the definitions of related concepts (immersion and presence) will function as the framework to help with the further analysis through case studies.

Method

Based on related secondary research and literature review, the aim is to develop our own definition of the degree of immersion necessary to understand achieving immersion with cognitive-related factors. In total 94 definitions addressed from 27 related references are analyzed; the list is attached as reference.

Based on the literature, we understand the “degree of immersion” as：

THE DEGREE OF IMMERSION is a mental description of how much people receive cognitive and perceptual transfer of consciousness. This could be enhanced by:

- the addition of sensory modalities including visual, audible and tactile.
- the narrative, which depends on the teaching context to influence emotion.
- full immersion in virtual learning, equal to “mental presence”.

The realization of presence, understood as a mental tool to achieve immersion, also requires further definition, especially from the perspective of sensory engagement. We found Heeter’s (1992) work most reliable to define the factors, since it is highly referenced within studies of psychology and presence. We visualized the framework into a 3D model, and further explains every factor under the sections of personal, social and environmental.

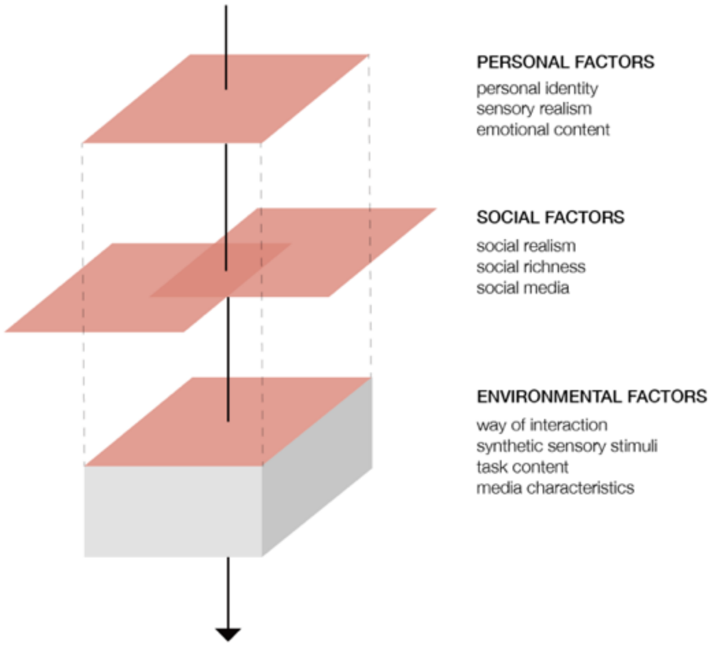

Figure 1. The 3D framework of factors of presence.

Personal factors

a) Personal identity: self-representation within a VLE, such as having a virtual body or entering the virtual world in a perceptual position. There are several evaluations to achieve certain personal identity, including: the sense of being there; the memory of "visiting" a place; and the emotional effect among activity and response to other participants' actions.
b) Sensory realism: the representations of reality in a perceptual system. The so-called reality here is not the fidelity of visual and sound quality, but whether one responds as if sensory data are real. Spatialized sound and kinesthetic references have positive effects on sensory realism.
c) Emotional content: the evocation of emotional factors such as fear, joy, stress etc. Positive factors such as enjoyment increase personal motivation and engagement in learning activities.

Social factors

a) Social realism: The extent to which other players react to participants. Having multiple participants (real or synthetic) appears to enhance the feeling of "being there", under the premise that their existence is natural and will not destroy the current context.
b) Social richness: the extent of daily social simulations within a VLE, including chatting, responding and co-working. Co-working positively affects socialized virtual environments, and it is preferred for educational applications.
c) Social media: the engagement of instant social medias, such as remote control, online communication and remote cooperation.

Environmental factors

a) Way of interaction: The way of interactions between participant and VLEs, including kinesthetic (tactile and proprioceptive sensations), voice control and behavior-response correlations. Natural feedback will enhance the self-identification of participants. The immediacy of control and feedback of participants' mental state appears to be important.
b) Synthetic sensory stimuli: the extent of sensory information which simulates the real world. The real-world refers to complex, perceivable elements, including the proportion of visual and audible predicates, tactile elements, olfactory elements and the fidelity of picture. They usually do not appear in isolation but interplay in a synaesthetic way. The overall combination of sensory stimulation should be focused on design needs, not the realism of actual visual and audible quality.
c) Task content: the task-driven activity been defined towards the learning purpose, normally related to "plot"

line (presenting an alternate self-contained world separate from the real world), storytelling and interactivity.
d) Media characteristic: the media form and content engaged within VLE, such as scene simulation, real-time creation and after-course evaluation.

Case Study 1: Immersive Exhibitions and Interactive Museums

The relationship between design education and virtual technology could develop a new integrated system. Design education has always been recognized, and is still always recognized, as highly creative and participatory. The benefits of virtual technology, with immersive simulations and flexibility of virtual dialogue, remain some of the key benefits for interactive and/or by remote didactic. In the twenty-first century, more sensory-involved technologies needed to be addressed by designers who are better equipped, leading to innovation in educational tools and methods.
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Case selecting and analysis method

The first group of case studies aims to take a look at existing approaches which aim to achieve “presence” through human senses and interactions within the virtual spatial environment. By analyzing immersive exhibitions, we aim to verify the groups of factors necessary to achieve presence, along with the different degrees of immersion. All the cases selected are based on a physical attainable environment, which differs from the virtual immersive environment of online courses and the exclusive use of virtual equipment.
Also, we review the factors of presence previously defined within these case studies; they are shortened as:
- Personal factors: personal identity; sensory realism; emotional content;
- Social factors: social realism; social richness; social media;
- Environmental factors: way of interaction; synthetic sensory stimuli; task content; media characteristic;
We organized the case studies into the following list; most of them are shown in the web-based platform.

Table 1. The list of selected case studies

• **Research Group**	• **Related Project Name**	• **Research Group**	• **Related Project Name**
• **IKEA**	• IKEA Blue City Dream Room	• Crystal Bridges Museum	• Ideum with Crystal Bridges Museum of American Art
• **Maotik & Fraction**	• DROMOS	• Cleveland Museum of Art	• Cleveland Museum of Art
• **Vedo**	• Vedo	• M9 Museo	• M9 Museo
• **Taste of Sound AB**	• Taste of Sound	• College Football Museum	• Obscure digital
• **Teamlab**	• Teamlab Restaurant	• Uffizi Virtual Experience	• Uffizi
• **Inside magritte**	• Inside magritte	• Museo storico dell'età veneta	• Museo storico dell'età veneta
• **HealthySim;**	• Group of	• Sarah	• Dun Huang

George's University Hospital; Van Gogh show; PARIS || Atelier des Lumières; DREAMED JAPAN	Studies: None-Interactive Immersive Exhibition	Kenderdine	Virtual Exhibition
• **The Cooper Hewitt Smithsonian Design Museum**	• WALLPAPER	• Tetrachromia	• Bird Vision
• **Sonos Studio SXSW**	• Playground	• Piet Mondrian Universale	• Piet Mondrian Universale
• **Ideum with National Cowgirl Museum and Hall of Fame**	• Western Design Room	• Anna Muksunova; Vadim Goncharov; Igor Yakovenko;	• Subtle States
• **San Francisco Digital Art**	• San Francisco Digital Art	• Dotdotdot	• VENCHI
• **MGM Cotai plaza**	• You Are Art	• Belle & Wissell	• Space Needle Skypad

Discussion: Typologies of Immersion within Immersive Experience

In general, we can recognize three types of interactions: "passive", "interactive" and "contributive". These categories illustrate the basic relationship between the human and synthetic environment: from a passive acceptance of structured information to a contributive approach that generates a new flow of information. This classification is further addressed and refined through the case studies.
Within this analysis, the identified four types of immersive environments are: passive sensory immersion; exploration-based immersion; knowledge-based immersion; user-contributed immersion. We selected 24 case studies under the categories identified to verify the degree of immersion.

Table 2. Types of immersion and the related case studies

• Type of immersion	• List of case study
• **Passive sensory immersion**	• Dromos; Vedo; Inside Magritte; Ikea blue city dream room; Teamlab restaurant; Taste of sound; Group of study: None-interactive immersion;
• **Exploration-based immersion**	• Wallpaper; Playground; Cleveland Museum of Art; Western design room; Crystal Bridges Museum; San Francisco Digital Art;
• **Knowledge-based immersion**	• College football museum; UFFIZI; Museo storico dell'età veneta; Dun Huang virtual exhibition; M9 Museo; Piet Mondrian Universale; Bird Vision;
• **User-contributed immersion**	• Venchi; Space Needle Skypad; You are art; Subtle states;

The factors of presence within are revised in the following table. Among them, passive immersion contains the fewest immersive elements, especially within personal and social factors. Personal identity does not appear in both passive sensory immersion and exploration-based immersion, nor does the social richness and social media function appear much within passive sensory immersion. Knowledge-based immersion and user-contributed immersion include all types of factors and verify through different needs. Based on the definition of "degree of immersion", we compare the factors related to sensory modalities and narrative components, including "sensory realism", "emotional content" and "synthetic sensory stimuli". By analyzing the effects and proportion of immersion, we therefore hypothesize that passive sensory immersion has the highest immersive experience paradoxically, while user-contributed immersion has the lowest level of immersion. As the most comprehensive environment involves all kinds of activities, knowledge-based immersion and exploration-based immersion are difficult to distinguish; we therefore place them in a parallel position. Their levels of immersion depend on several aspects, including: the natural response of human-computer interaction; the agreement between sensory design and the theme of activity; and the design of the task and the skill of narrative.

Table 3. The table shows the "factors of presence" existing within four types of immersion

Type of immersion	Factors of presence									
	Personal factors			Social factors			Environmental factors			
	personal identity	sensory realism	emotional content	social realism	social richness	social media	way of interaction	synthetic sensory stimuli	task content	media characteristics
Passive sensory immersion		✓	✓	✓			✓	✓		
Exploration-based immersion		✓	✓	✓	✓	✓	✓	✓	✓	✓
Knowledge-based immersion	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
User-contributed immersion	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

We further explain every type of immersion and their features and usability.

Case selecting and analysis method

The passive sensory immersion emphasizes the passive reception of sensory simulation. Participants within the virtual environment have a lower degree of manipulation, but a higher level of passive receiving. Most of the exhibitions use passive sensory immersion to provide an emotional "tour" and a unique sensory experience.
In this kind of immersive experience, social interactions are very limited, and we understand them as not essential to achieve immersion. Both direct and indirect (not with body movement but physical tools) interactions are designed to fulfill specific goals. There are two patterns to enjoy the sensory performance: audible-visual passive receiving and partly interactive props engagement. The second pattern could provide some tactile supplements and simulate a more realistic environment that is similar to real life.
It is possible to identify three specific objectives which passive sensory immersion aims to reach:
1. to create a specific feeling or atmosphere.
2. to support a virtual narrative and convey information (differing from traditional learning materials such as a desktop).
3. to optimize synaesthetic experience, such as sound to taste and visual to taste.

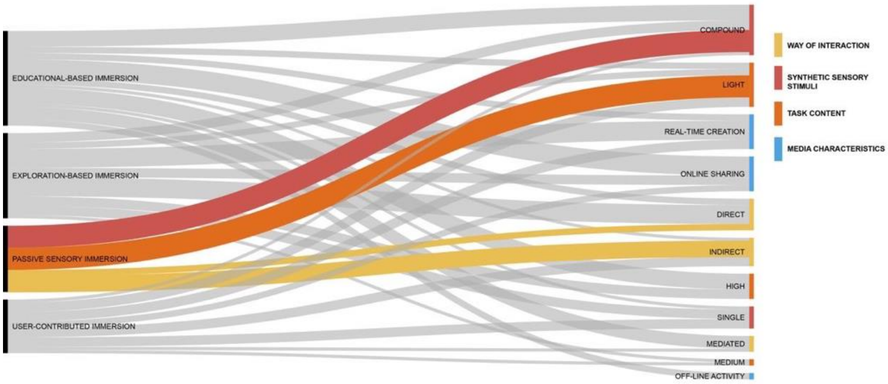

Figure 2. Relations between passive sensory immersion and the factors of presence (take environmental factors as an example)

Exploration-based immersion

Exploration-based immersion sees frequent use within art and design museums. It has been revitalized within interactive exhibitions. Through a certain level of interaction, some museums aim to simply provide a delightful experience or convey light messages. Within these studies, the message given is not rigid; rather, the vague content aims to create certain cognitive involvement. Participants can also achieve immersion through physical interaction. What makes exploration-based immersion special is the way in which it achieves immersion through interactive activities, which is significantly different from passive sensory immersion. Social factors are at the center of exploration-based immersive environments. Multiple visitors are encouraged to participate since co-working and social communication are important to art creation. Compared with passive interaction, the ways in which participants communicate and explore content are much more enriched. The size of the physical environment (space) is "narrowed" compared with large open spaces, partly because some activities involving educational tasks needs visitors to focus, which means distracting elements require reduction.

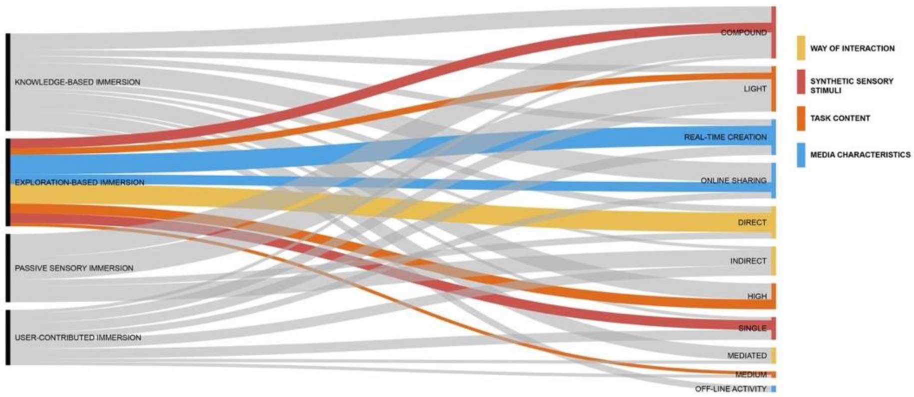

Figure 3. Relations between exploration-based immersion and the factors of presence (take environmental factors as an example)

Knowledge-based immersion

Knowledge-based immersion refers to an immersive experience that is framed by clear themes and aims to transfer information and knowledge. The expression "knowledge-based" can also be conveyed as "education-based" or "information-based". Most case studies have a clear identification of educational themes supported by a wealth of immersive tools and interactive methods. Personal identity appears in knowledge-based immersion in the form of both first-person and third-person perspectives.

This kind of immersion encourages comprehensive social environments wherein participants can interact and co-work within the same space. Moreover, since the dissemination of knowledge requires media assistance, venue resources are also fully utilized. Socialization has reached the highest level, as the open place supports almost every kind of social communication. As to the way of interaction, it is preferrable to call participants "players", as playful content seems to optimize the experience. The designers use bodily interactions to both enhance immersion and fulfill specific tasks.

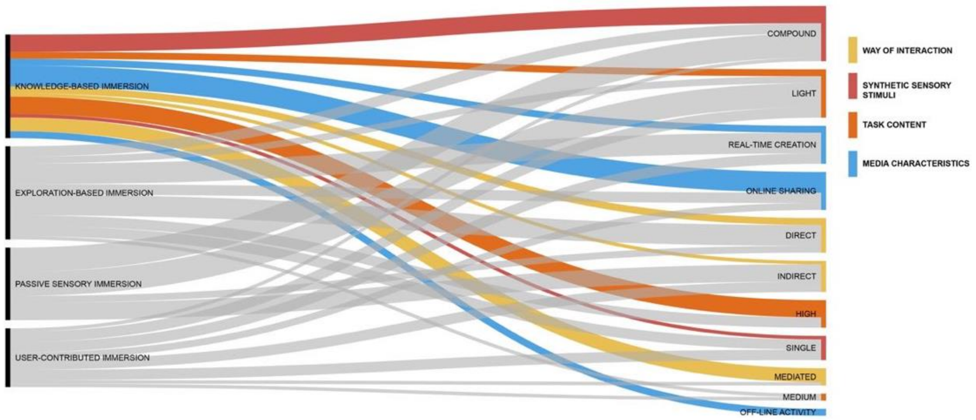

Figure 4. Relations between knowledge-based immersion and the factors of presence (take environmental factors as an example)

User-contributed immersion

Within user-contributed immersion, information is constituted by users, and the display engaged is only for organizing, analyzing or displaying. The performance of participants reaches the highest level among the four types of immersion, since user behavior is the main component, and real-time response is key to supporting this kind of activity.

Mediated and indirect interactions are preferred within user-contributed immersion. Real-time response is the key to directly involving participants by having them form the experience in near totality. Concerning the media characteristics, real-time media translation creates conversation between content and participant. User-contributed content includes subjective expression, tasting, body movement and virtual personal data.

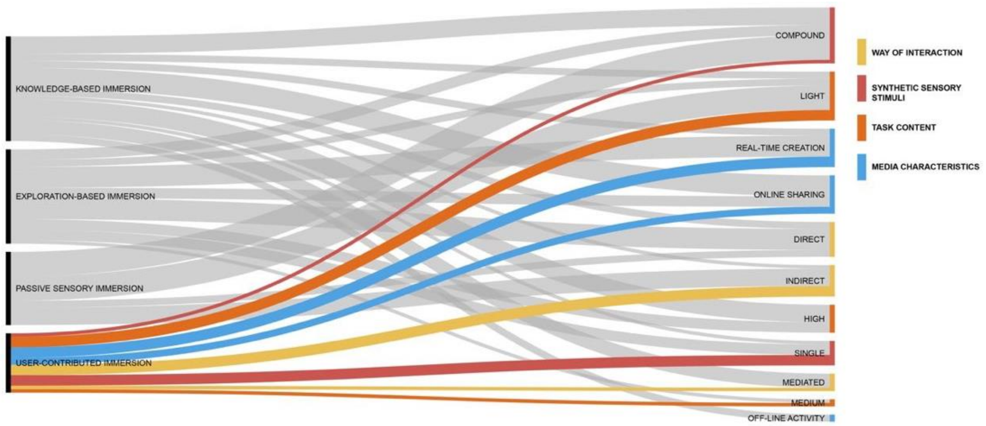

Figure 5. Relations between user-contributed immersion and the factors of presence (take environmental factors as an example)

Case Study 2: Educational Activities Within VLEs

Case selecting and analysis method

Case selecting

After identifying the typology within immersive environments, we further study associated educational practices that benefit from immersive learning. What differs from the case study 1 is our attention towards the course structure and task. We focus on analyzing the formulation of applicable tasks and three ways of interacting (Moore, 1989) as a means to provide support for course design. The field of selection contains desk research from scientific databases including Google Scholar, Semantic Scholar, Scopus and Web of Science from 2009-2020 (last 10 years); video/image materials; and personal interviews.

To conduct a more systematic and scientific research, we go through a careful case selection process starting from identifying the keywords through databases. We define the main keywords as “immersive learning environment” and “education”; however the keyword “immersive learning environment” is quite general and it contains other technologies such as VR, AR, and online learning projects. We therefore replace the keyword with “CAVE” (Cave Automatic Virtual Environment), which is a very typical and widely applicated VLE. We also consider the keyword “education” to be congruent with “teaching” and “learning”.
We found, in total, 80 related papers to further consider. We reduced the amounts of papers related to the content, considering the degree of perfection of the teaching process and the depth of discussion on immersive factors. Finally, we identified 14 best practices following the following selecting roles:
1. the purpose of the study is to fulfill an educational task, or the experimental process is educational;
2. the process of the research is well observed and recorded (through scientific description or supported materials), to better cover the three features of virtual reality and provide enough detail for the analysis;
3. the curriculum/ training is fully designed to exert the potential of an immersive learning environment.
The final list of case study 2 is as below:

Table 4. The list of case study 2 selected from scientific papers and web-based platforms

Research Group	Reference
Kyan, M., et al.	Kyan, M., et al. (2015). An approach to ballet dance training through ms kinect and visualization in a cave virtual reality environment. ACM Transactions on Intelligent Systems and Technology (TIST), 6(2), 1-37.
Collins, K., & Borowski, K.	Collins, K., & Borowski, K. (2018, August). Experimental Game Interactions in a Cave Automatic Virtual Environment. In 2018 IEEE Games, Entertainment, Media Conference (GEM) (pp. 1-9). IEEE.
Voto, D., Viñas, L. M., & D’Auria, L.	Voto, D., Viñas, L. M., & D’Auria, L. (2005). Multisensory interactive installation. Sound and Computing, 5, 24-26.
S. Fernando. & B. Barbara.	www.harvardmedsim.org
POLISOCIAL	https://ludomi.polimi.it/
Matsentidou, S., & Poullis, C.	Matsentidou, S., & Poullis, C. (2014, January). Immersive visualizations in a VR cave environment for the training and enhancement of social skills for children with autism. In 2014 International Conference on Computer Vision Theory and Applications (VISAPP) (Vol. 3, pp. 230-236). IEEE.
Yuen, K. K., Choi, S. H., & Yang, X. B.	Yuen, K. K., Choi, S. H., & Yang, X. B. (2010). A full-immersive CAVE-based VR simulation system of forklift truck operations for safety training. Computer-Aided Design and Applications, 7(2), 235-245.
ExxonMobil Research Qatar; EON Reality Inc;	https://www.eonreality.com/portfolio-items/immersive-3d-training- environment/
University of Liverpool	https://www.youtube.com/watch?v=j40fDpnryEU
the Institute of Technical Education (ITE)	https://www.eonreality.com/portfolio-items/virtual-technology-training/
EON Reality	https://www.eonreality.com/portfolio-items/virtual-anatomy-simulation/?portfolioCats=609
Loscos, C., et al.	Loscos, C., et al. (2004). The Museum of Pure Form: touching real statues in an immersive virtual museum. In VAST (pp. 271-279).
Formula D Interactive; Frost Museum of Science in Miami	https://www.formula-d.com/projects/virtual-everglades-tunnel/
Laia Cabrera; Isabelle Duverger	https://www.laiacabreraco.com/illusion

Analysis method

The method of analysis is addressed on the basis of three basic aspects of VR, stemming from the research of Burdea and Coiffet (2003), detailing “immersion”, “interaction” and “imagination”, also inspired by the constructivist approach by Huang, Rauch and Liaw (2010). The details are adjusted according to the needs of studying design-related, course-related elements, including synaesthetic approaches.

The analysis method contains several areas of focus:

1. a focus on the sensory engagement, especially with concern to how audible/visual/tactile contents are used to achieve specific teaching effects, and the combinations within (synaesthesia approach) to achieve immersion;
2. a focus on the modes of interaction through “learner-instructor-content”;
3. a focus on the course framework and assessment.

Discussions: Typologies of Immersive Learning Within VLE

In this section, we discuss the two changes that basic design education faced: one is the teaching need of transformation from visual to multisensory and synaesthetic communication; the other is the use of virtual environments to teach design. Therefore, we are able to hypothesize the concept of immersion (usually provided by virtual learning environments) as an innovative teaching method for design.

Behavior correction

The model of behavior correction passes out functional knowledge mapped into relevant interactions such as providing supplementary action guidance or giving correct answers. The behavior correction educational model has clear training goals, such as dance training, problem solving under specific scenes, or remembering certain knowledge (theory or application).

Two sub-categories are classified: motion correction and info/knowledge correction. Motion correction focuses on rectifying movements and behaviors, usually equipped with a virtual teacher to demonstrate correct behavior. The info/knowledge based model will give the correct answers and verify them with pre-set questions. The expression of “correct” does not always refer to a certain answer, but instead it also includes the correction of cognition and the understanding of specific concepts.

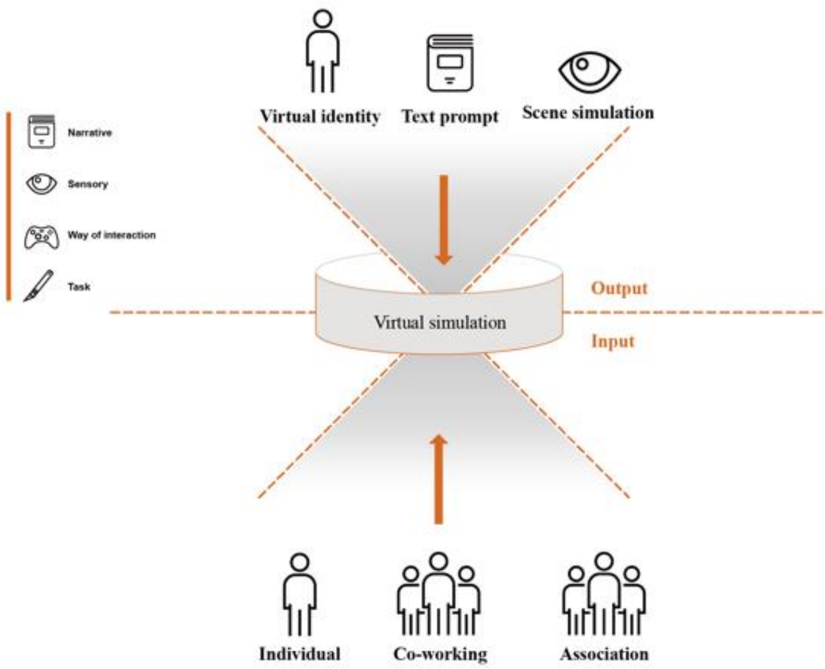

Figure 6. The model of behavior correction for virtual simulation, wherein, both individual and group participation are allowed

As shown in Figure 6.1, within the behavior correction model, human-environmental interactions remain simple. Three types of participations are engaged: individual work, co-working and association. Co-working means multiple users working together for a common decision or discussion facing the same problem. Association specifically refers to family engagement for children's educational activities, such as parental escort or guidance from guardian.

Virtual simulation is mostly framed as a pre-set scene with sensory engagement, wherein virtual content largely depends on the progress of task completion, not the performance of participants. Three main types of reflection are given:

1) text prompt: the text to guide the student's behavior;

2) virtual identity: including the virtual teacher which could provide correct action instructions; or virtual identity such as an avatar; or virtual co-workers to create a certain working scene;

3) scene simulation: the scene like behavioral guidance (e.g. animation and demonstration).

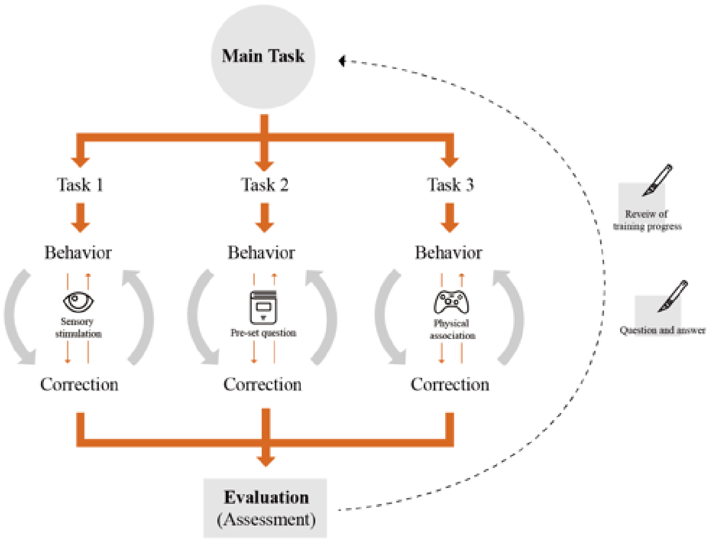

Figure 7. The model of behavior correction between task and evaluation

For the behavior correction model, the teaching process is mainly guided by groups of tasks in parallel. Rich teaching content is implemented by laying out a knowledge framework, setting after-class questions, and adjusting according to students' feedback. These tasks largely depend on the course designer (usually the teacher), not the activity or ability of the students.

Normally, the study identifies one main task and then splits it into several groups of specific tasks. Missions are given such as "guarantee your team's safety", and the program simulates different scenes of weather situations to imitate varying and unexpected situations.

Three types of reflection are provided to value the behavior of participants:

1) sensory simulation: certain visual or sound simulation for correction, such as red lights or sound prompts during mis-operation;

2) pre-set questions: to evaluate the effectiveness of the work through provided questions, which can appear during progress or at the end of an activity.

3) physical association: the indication from member or teacher.

Generally, the tasks within educational activities present a linear state; that is, one task corresponds to one answer. Sometimes, the content of the course is adjustable according to the results of evaluation, which also depends largely on the assistance and role of a "teacher". The evaluation (assessment) process can be fulfilled by reviewing training progress, or by question and answer in the form of text prompt.

Free exploration

The free exploration model refers to learning that happens naturally during the exploration of the virtual environment. This approach focuses more on the experience and fun during the learning process. Normally, free exploration happens within an open space, while the program provides virtual sensory content including visual, auditory and textile stimulations using interactive formats. The participants are usually divided in

groups wherein open social communication is welcomed.
The interaction between the participants and environment could be understood as a circle, as there is no clear directionality between the participants and virtual contents. These interactions exist not only between learner and content, but also between participants. They are able to fulfill the tasks through physical movements thanks to motion tracking or physical tools. The output from the virtual simulation remains in the area of visual display, while spatial sound and textile stimuli (with the support of gloves) reframe the realism of a certain scene or enhance the emotional experience. Compared with the focus of a certain sense, this usually emphasizes the coordination between senses.

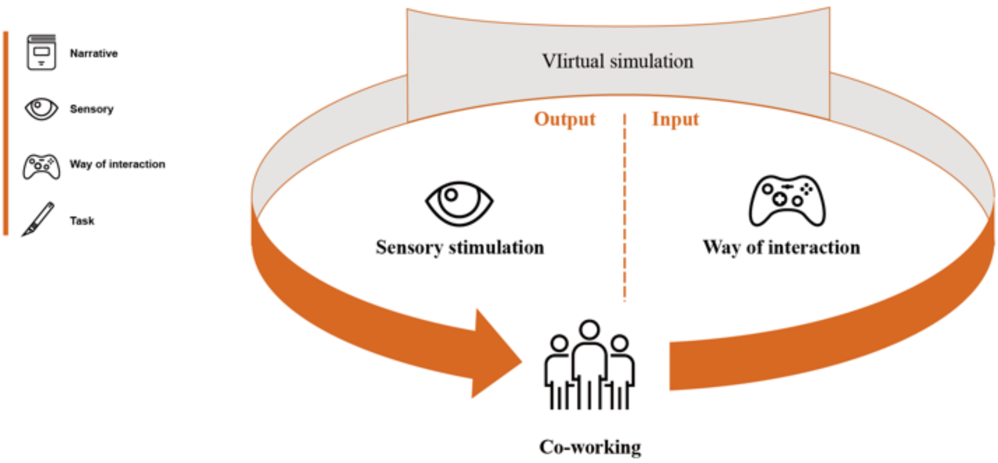

Figure 8. The model of free exploration for virtual simulation, wherein, sensory simulation and interaction are the two essential ways to create virtual simulation

Free exploration often appears in educational exhibitions under a broad premise, wherein certain themes might involve enjoying nature, exploring statues, or conducting art exploration. The themes identified can be understood as main tasks, and there is a triangle framework involving the “main task”, “behavior” and “reflection”, as shown in Figure 6.4. Unlike the behavior correction model, the participant's behavior affects the virtual content, and even makes new contributions continuously. Virtual contents are first provided under the form of sensory simulation, background story and physical association, and participants act on content through body interactions. Reflections from participants act on the virtual content through sensory input and scene, while the main task transmits into the participants’ attribution.

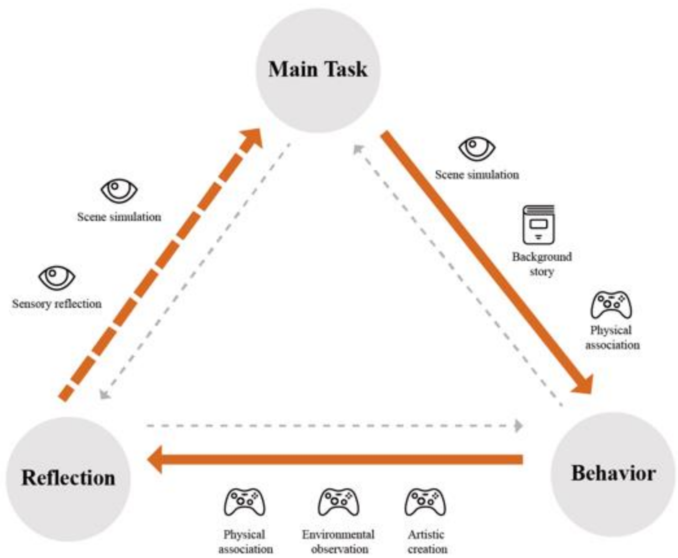

Figure 9. The model of free exploration between task and evaluation

The knowledge spreads in a softer way compared with behavior correction models. Indeed, during the experience, participants need not remember or evaluate much knowledge. This form of learning allows a wider range of interactions and sensory engagement, and more possibilities for social communication. This method is more suitable for comprehensive experience activities, while behavior correction models can play a role in specific knowledge dissemination and acquisition.

Conclusion

The relationship between design education and virtual technology could develop a new integrated system. We consider the technological involvement of virtual tools based on the demands of sensory training, which has been studied for decades, yet the teaching tools still rely heavily on traditional methods. In the twenty-first century, more sensory-involved technologies needed to be addressed by designers who are better equipped, leading to innovation in educational tools and spaces.

Instead of focusing on the technically driven parts of virtual technology, we focus on the experience provided by virtual reality: the feeling of immersion. Although we discuss CAVE as the existing suitable environment for basic design teaching, any virtual tool that provides immersion - even online platforms - could be an effective platform for learning activities.

This research understands the experience of immersion on the cognitive level and further explores the content under sensory engagement and virtual narrative. As there is extremely limited research into design learning alongside virtual technology, we believe it essential to conduct theoretical investigations with a basic and solid method. Therefore, two groups of case studies are driven for the theoretical support for the framework proposed to achieve immersion for instructors.

The first group of case studies includes 24 spatial virtual exhibitions, while the second group of case studies includes 14 scientific learning approaches. Four typologies of immersion (passive sensory; exploration-based; knowledge-based; user-contributed) are categorized, and related factors of presence are addressed to support achieving different types and degrees of immersion. Two in-class models are presented: behavior correction and free exploration.

For the second phase of applying this framework, we consider several general research plans. The most reliable one is to discuss what kind of sensory interactions are adaptable within a CAVE-like learning field, and how to claim the current framework for immersive learning.

We understand this approach as the starting point to design an actual usable tool for instructors to teach basic design with immersion. Course structures and interactive formats can be adapted straightly by the engagement of web-based tool. We consider this part of the research as the second path. Since the content of basic design is also innovating and constantly producing new knowledge, this subject is also constantly evolving and requires constant exploration.

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