MODELLING OF IMMERSIVE SYSTEMS FOR COLLABORATIVE DESIGN

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Abstract

This paper proposes to explore the concepts related to immersive situations for collaborative design. The term immersion is investigated depending on the analysis of its constitutive elements, i.e. the actors and the workspace. Based on the feedback of experiments performed in the design process of products, a proposition of categorization of the actors and workspaces gives a conceptual basis for the modelling of immersive systems. An application with educational institutions supports the proposal and aims to prove the efficiency of immersive strategies.

Keywords: Collaborative design, immersion, Process modelling

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1 INTRODUCTION

The immersion of students during a short-term overseas program is a well-known technique to accelerate the learning of a new language. It has been prove that an immersive process allows a better concentration and memorization of the language (Lee 2009). The term immersion expresses the idea that actors are temporary placed in a new environment to acquire new knowledge. The success of the immersion will depend on the duration of the placement, the novelty of the environment and the quality of the activities performed by the actors. Based on this principle, it is possible to define many immersive modes by varying the type of actors and the type of environments. It is agreed that if the activities are temporary and if the environment is new, the actors are in an immersive situation. The situations are numerous and can be used for fun or for professional purposes. For example, virtual worlds can help designers in sharing information for collaborative design (Koutsabasis, 2012)(Fillatreau et al., 2013), and especially when designers are geographically distributed (Wang et al., 2014). The senses of the designers are focused on the activities in the virtual environment and can consequently acquire new knowledge (Lorenzo et al., 2012). All those situations are immersive experiments, but they represent only a part of possible immersive modes. Immersive systems can offer new opportunities, they have not been deployed widely for companies in order to create collaborative economic value at a territorial level.

To address this lack, the paper proposes to analyse the concept of immersive systems to support collaborative design processes. First, a theoretical framework highlights the concepts of immersive modes to explain the relationships of actors in a workspace. Second, an operational understanding is given by detailing and assessing immersive experiments used in the design process of products. In addition, the usefulness of mutualisation and substitution activities resulting from the immersive modes is highlighted. In the third section, a case study describes the implementation of the immersive framework for a collaborative design process in the culinary sector. Finally, a discussion expresses some recommendations from practical and theoretical viewpoints.

2 IMMERSIVE SYSTEMS

2.1 Immersive modes

The concept of immersive mode is central, it is related to the relationships that an actor has in a workspace. The domain of virtual reality gives a preliminary understanding of these relationships. The typology developed by (Messinger et al., 2008) gives five elements (purpose, place, platform, population, profit model) aiming at the description of immersive systems. Depending on the attributes of the elements, different applications can be proposed. For example, Second Life (SL) constitutes one possible configuration of the immersive modes, it is a popular multi-user virtual world platform being used in education. Despite its potential for teaching (Warburton 2009) or for user innovation and entrepreneurship (Chandra and Leenders, 2012), SL and similar platforms face technical, human and social barriers that can only be solved by additional physical immersive situations. This is the case of a collaborative design process of products requiring tactile and/or olfactory skills, as for the one proposed in section 3. In order to promote further study and application of immersive systems, a typology is proposed to identify the relationships of actors in a real and virtual workspaces.

The way the actors act in the workspace depends on their form and their role. Form and role respectively represent the structural and functional knowledge of the immersive system.

In the context of human centred approach, the form defines the structure of an entity which can be physical or virtual. A physical actor can be a customer purchasing goods in a grocery store (physical workspace) or purchasing goods in an e-commerce website (virtual workspace). Physical actors are humans and physical workspaces are made of equipments (machines, devices, …). Virtual actors are numeric entities (3D avatar, …) and virtual workspaces are numeric space (virtual 3D space, database, …). A more detailed typology of virtual worlds can be used, but at this time the level of abstraction of the modelling doesn't require this precision.

The role of an entity defines the accuracy of its identity which can be simulated or real. A physical actor can simulate a disease or can be a real sick person. A 3D numeric environment in a videogame is a simulated environment, while an e-shop on internet is a virtual space for real economic activities.

An immersive system can be abstracted by its entities which are respectively described by their form and role. The following definitions summarize the proposition:
Definition 1: an immersive system S_i is made of actors A_i acting in a workspace W_i. $S_i = (W_i, A_i)$.
Definition 2: the form of an element expresses its structure which can be physical or virtual (numeric). Form={physical;virtual}={P;V}.
Definition 3: the role of an element expresses the accuracy of its acts which can be simulated or real. Role={simulated;real}={S;R}.
Definition 4: An immersive mode Im of an immersive system S_i represents a configuration of its elements (i.e. workspace W_i and actors A_i) depending on their attributes form and role which can respectively take the value {physical;virtual} and {simulated;real}. Im(S_i)=((form(Wi), role(Wi)), (form(Ai), role(Ai))).
Axiom: an actor acts in a workspace only if their forms are similar.
By applying the values to the attributes and by respecting the axiom, eight immersive modes can be stated. They are listed below and illustrated with some examples.

- Im(Si)=((P,S),(P,S)).
- Im(Si)=((P,S),(P,R)).
- Im(Si)=((V,S),(V,S)).
- Im(Si)=((V,S),(V,R)).
- Im(Si)=((P,R),(P,S)).
- Im(Si)=((P,R),(P,R)).
- Im(Si)=((V,R),(V,S)).
- Im(Si)=((V,R),(V,R)).

The immersive mode Im(S_i)=((P,S),(P,R)) can be illustrated by a physical customer purchasing goods in a physical experimental shop. This mode is used to evaluate the potential sales of goods in a controlled environment (track eyes, videos recording, …). The immersive mode Im(S_i)=((P,R),(P,S)) can be illustrated by a designer simulating handicap to test the performances of a product (ice sled case, Figure 3b).

2.2 Transition between immersive modes

An immersive system is dynamic, it can evolve depending on the changes of its elements. When elements change, a transition is created between two immersive modes.
Definition 5: a transition Tr_k between two immersive modes Im_i and Im_j expresses the change of attributes belonging to Im_i into attributes belonging to Im_j.
By changing the value of the attributes, twelve configurations can be stated. Three of them are showed in Figure 1 and explained below.

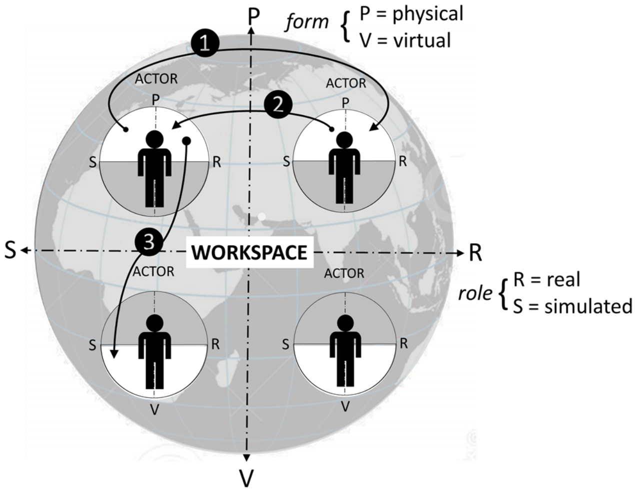


Figure 1. Transitions between immersive modes (actors in workspaces)

- Tr_1= (((P,S),(P,S)),(P,R),(P,R)).

Transition Tr_1 can be illustrated by a physical actor simulating an handicap on an ice sled simulator (immersive mode ((P,S),(P,S))) who becomes a real disabled person playing on a real ice sled (immersive mode ((P,R),(P,R))).

- Tr_2= (((P,R),(P,S)),(P,S),(P,R)).

Tr_2 can be illustrated by a physical actor simulating an handicap on a physical ice sled (immersive mode ((P,R),(P,S))) who becomes a real disabled person playing on a physical ice sled simulator (immersive mode ((P,S),(P,R))).

- Tr_3= (((P,S),(P,R)),(V,S),(V,S)).

Tr_3 can be illustrated by a real disabled person playing on a physical ice sled simulator (immersive mode ((P,S),(P,R))) who becomes an avatar in a virtual game simulating a handicap to play on a virtual ice sled (immersive mode ((V,S),(V,S))).

Note that the control of an immersive system can be done by its transitions. The control consists in minimizing the expenditure during the transitions in order to maintain the stability of the system.

2.3 Configuration space

An immersive system is made of several actors acting in different workspaces. The resulting set of immersive modes represents the configuration space of the system. A configuration can be independent, it means there is no interaction between the immersive modes of the involved actors. A dependent configuration contains at least one actor in immersion in a workspace belonging to another actor. In the case of a dependent configuration space, two referent configurations of immersive modes emerge:

- Mutualization: two actors (or more) act in the same workspace, they have the same role.
- Substitution: an actor (or more) takes the role of another actor.

In the domain of industrial ecology (Brullot and Maillefert, 2008), mutualization and substitution aim at the improvement of economic, environmental and social performances. Companies can be more stable and competitive by mutualizing or exchanging energies, raw materials, wastes, human resources, etc. The establishment of a powerful immersive system will consist in creating mutualization and substitution configurations.

2.4 Immersive experiments

From a general point of view, an immersive process observes and assesses the behaviour of actors in a workspace. In order to extend the application fields outside conventional situations (language immersion, virtual simulation) some experiments encountered during the design process of products are detailed below. They are two examples describing immersive situations performed by designers of sport products.

2.4.1 Product for blind archer

The first example concerns the redesign of a mechanical system to help blind persons to practice archery. An academic design team has been created to understand the behaviour of blind persons and to assess the failures of the existing product. In the first step, members of the design team simulated blindness (with a sleeping mask), with the objective to live during one day like a real blind person (first immersive situation, Figure 2a). The simulating persons were accompanied by a real blind person who became their teacher for a day (second immersive situation). Feedback of the experiment gave important information on blindness to the design team. They also met blind competitors during a national archery contest (third immersive situation) to understand their behaviour with the existing mechanical system. All the gathered information has been then translated into a functional specification, a new product has been designed and jointly tested by the designers and blind persons (fourth and fifth immersive situations, Figure 2b).

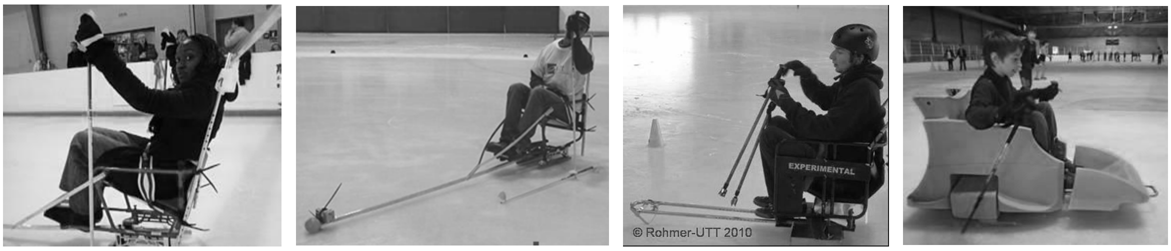
(a) (b)

Figure 2. Blindness simulation (a), test of the new product (b)

For this experiment, five immersive situations are identified. Three are related to the designers who successively simulated blindness, practiced archery, and tested prototypes. The two other situations serve at a better understanding of the users and their behaviour. The immersive situations have accelerated the design process avoiding back and forth during the development of the prototype. The designers have been able to target the failures of the existing system and to propose the right solution (system with haptic technology).

2.4.2 Product for disabled ice skater

The second immersive experiment concerns the design of a product aiming disable people to practice ice skating. The design team first met disable people (first immersive situation), their family and medical staff to discuss about handicap and their need by regards to the product. Then, the designers and disable people tested an existing ice-sled (second and third immersive situations, Figure 3a) to gather technical information and sensations. Camcorders and sensors have been mounted on the sled (Figure 3b) to record information on sportive gestures and audio feedback (verbalization in real time). Based on the resulting information, the designers created a prototype which has been tested by themselves and by disabled persons (fourth and fifth immersive situations). After the validation of the prototype (Rohmer and Feng, 2013a), the product has been patented (Rohmer 2011) (Figure 3c) and is currently distributed by a company.



(a) *(b)* *(c)* *(d)*

Figure 3. Handicap simulation (a), instrumented test (b), prototype (c), new product (d)

For this experiment, four immersive situations are related to the designers who successively met disabled persons, simulated handicap to test existing products, as well as the prototype and the final industrial product. The immersive situations accelerated the research and the development of the product. The problem of stability of the user on ice has been highlighted, aiming at the design of a perfectly suitable product.

2.4.3 Advantages of immersive situations

The experiments show that immersive situations are profitable for both designers and users. The immersion significantly accelerates the design process, it gives a better understanding of the user (his job, his behavior, his need) and of the environment of the product. Consequently, the immersive situations give a better definition of the functions related to the product in order to propose the best solutions.
An immersive reasoning can be a decisive element for a successful innovation. In the second experiment, the company which distributes the new ice-sled has been awarded by the French Regional Council of Champagne Ardenne and by the international exhibition Midwest in 2011.

2.5 Operational implementation

The implementation of an immersive strategy must be performed with a clear and rigorous process. Based on the experiments feedback, a pragmatic process to create powerful immersive systems can be formalized as follows:

- Mapping of the actors and workspaces, and definition of their respective role and form.
- Identification of the current immersive modes, identification of the potential immersive modes.
- Selection of the new immersive modes.
- Implementation of the immersive system.

Some recommendations can be given in order to respect a sustainable strategy. A territorial approach must be first considered. The search for partnerships should privilege local actors. This will simplify the organisation of the immersive system (transportation, better responsiveness, …) and will decrease the expenditures while highlighting local skills. From human factor viewpoint, immersive situations can be confusing and disturbing, the manager of the immersive process must ensure that all actors appropriate the principle. A restricted immersive test can be first performed with representative actors.

3 CASE STUDY

3.1 Context and objective

Previous researches in the culinary sector proved that papers can be crumpled in a structured way (Floderer, 2008) to create innovative culinary moulds (Rohmer et al., 2014a). Prototypes have been designed (Rohmer et al., 2014b) but their industrial feasibility must be established. For this purpose, a research and development program must be engaged with professionals in the culinary sector to design operational crumpled baking paper moulds (CBPM). Moreover, managerial constraints force to develop a low-cost project and to respect territorial considerations in terms of sustainable development.

To address this problem while respecting the constraints, the immersive approach is used as a methodological framework. The operational implementation defined in section 2.5 is applied and described below, it should result in a reliable configuration space.

3.2 System definition

3.2.1 System boundary

The actors involved in the project are members of a university (teachers, students) and professionals in origami techniques. For economic and environmental considerations, the immersive program must be established at a regional level, should take into account territorial heritage, should highlight culinary excellence of partners invested in the production of goods and culinary services.

Based on these prerequisites, the following new actors have been chosen: teachers and apprentices of a local culinary school, a local chocolate factory (chocolate world champion).

In order to reduce the boundary of the system, only the applications for pastry, bakery and room service of the pedagogical restaurant of the culinary school are concerned. The restaurant serves at the operational test of the culinary moulds. Pedagogical and research objectives are assigned to researchers and teachers. For the culinary school, apprentices skills must be increased while stimulating creativity. For academics, the objective is to obtain technical feedback on the operational usage of the culinary moulds while evaluating the students skills during the research program. The project is called Certification of Culinary Origami $(CO)^2$.

3.2.2 Actors and workspaces mapping

The actors and the associated workspaces with their attributes are listed in Table 1.

Table 1. Actors and workspaces

actors and workspaces			form		role	
			P	V	S	R
actors	culinary school	apprentices	x	x		x
		teachers	x	x		x
	university	students	x	x		x
		teachers	x	x		x
	origami group	origami professionals	x	x		x
	chocolate factory	chocolate world champion	x	x		x
workspaces	culinary school	pedagogical restaurant	x			x
		classrooms	x	x	x	x
	university	laboratories	x	x	x	x
		classrooms	x	x	x	x
	origami group	laboratory	x			x
	chocolate factory	shop	x	x		x
		laboratory	x			x

The mapping can generate eleven possible configurations (form, role) for the actors, and sixteen possible configurations (form, role) for the workspaces. Virtual actors represent people with a virtual identity for numeric purposes. Virtual workspaces are numeric applications, they can be used as real workspaces (e-commerce) or simulated workspaces (e-learning applications).

3.3 Immersive modes

3.3.1 Initial configuration space

The initial independent configuration spaces correspond to the list of all immersive modes belonging to the partners. The following three examples illustrate some immersive modes.

- Im_1=(pedagogical restaurant (P, R), apprentices (P,R)),

In this case, the apprentices work at the pedagogical restaurant which is a real restaurant with real customers.

- Im_2=(university virtual classroom (V, S), students (V,R)),

Im_2 is made of students working with an e-learning application.

- Im_3=(chocolate factory e-shop (V,R), chocolate factory administrator (V,R)),

Im_4 is made of a website administrator managing the e-shop of the chocolate factory.

3.3.2 Analysis of potential immersions modes

The objective is to transform the previous independent configurations into a dependent organization made of activities that mutualize and/or substitute resources. By analogy, immersive modes appear when different actors intervene for the same activity or when actors temporary act in a new environment. The functional organization of the $(CO)^2$ program must be a network of shared activities performed by actors.

In order to identify the new immersive modes, a representation of possible interactions for the activities performed by the actors is detailed in Table 2. A list of activities is given in order to identify the possible interaction of the actors. An actor is related to an activity by using the formalism given by SADT method. An activity is formalized by a verb (A) supported by a mechanism (M) that transforms input (I) into output (O) managed by controls (C). Depending on the activity, an actor can intervene or not as M,I,O or C. A mutualizing activity involves at least two data (I or C) from different actors sharing the same mechanism (M). A substituting activity contains data (I, M or C) belonging to an actor that is respectively substituted by data (I, M or C) from another actor. A collaborative activity shares different data (I, M, C) belonging from different actors, and an independent activity is performed by a unique actor.

The analysis of Table 2 shows that two substitutions can be found. For the activity *validate apprentices work*, the students can be involved to verify the culinary foodstuff proposed by the apprentices; respectively the activity *validate students work* can substitute academics teachers by apprentices.

Two mutualizing activities can be found. For the activity *teach origami*, origami professionals can teach both students and apprentices. For the activity *validate certification*, origami professionals and the chocolate world champion can validate the certification for both students and apprentices.

Only one collaborative activity is found, it is the interview of the apprentices and their teachers by the students.

Finally, there are three independent activities: *design* performed by students, *crumple* and *install* performed by apprentices.

The new immersive modes can be then related to the mutualization and substitution activities. Some of the immersive modes are listed below.

- Im_1=(culinary classroom(P,R), students(P,R)); related to the activity *teach origami* by origami professionals.
- Im_2=(culinary classroom(P,R), students(P,R)); related to the activity *validate apprentices work*.
- Im_3=(academic classroom(P,R), apprentices(P,R)); related to the activity *validate students work*.
- Im_4=(pedagogical restaurant(P,R), students(P,R)); related to the activity *interview*.

The immersions modes contain the attributes physical (P) and real(R) expressing the reality of the actions done by physical actors in physical environments. It doesn't mean that virtual environments cannot be useful, they could appear in sub-activities in a more detailed development of the (CO)² program. As for example, the students could use software to simulate the transformation of papers into three dimensional structures.

Table 2. Shared activities

activities/actors	Culinary school		University		Origami professionals	Chocolate factory
	apprentices	teachers	students	teachers		
cook foodstuff	M	C				
design culinary origami	M		M		C	
interview	I	I	M	C		
validate crumpled objects		M			C	
teach origami	I	I	I		M	
crumple culinary objects	M				C	
validate students work	M	M	I	C		
validate apprentices work	I	M	M			
validate certification	I		I		M	M

3.3.3 New configuration space

The final configuration of the resulting activities is illustrated in Figure 4 with a SADT representation.

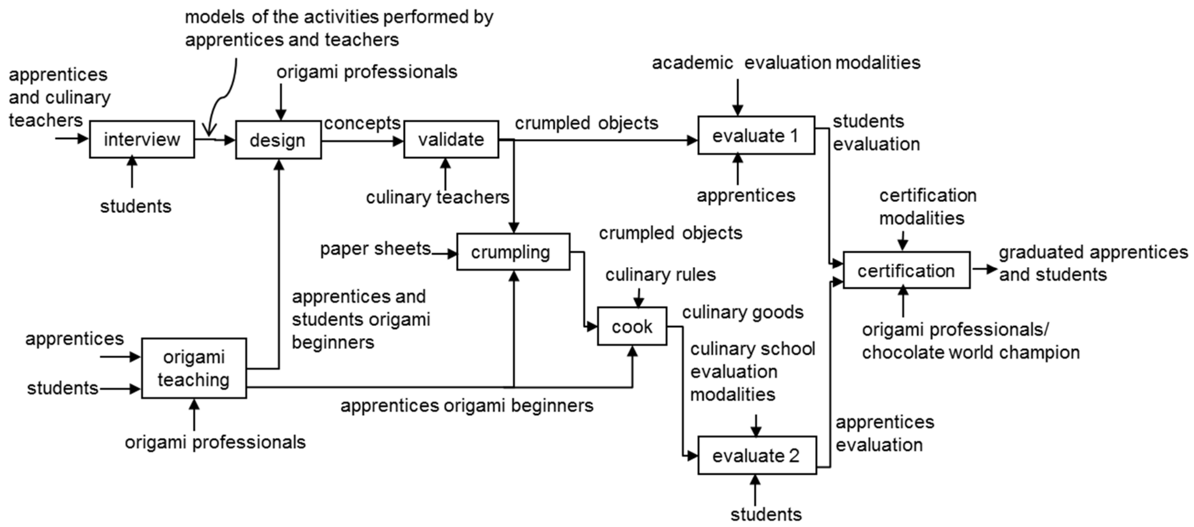


Figure 4. Activities of the immersive system

In this system, students are immerged at the culinary school in order to understand the activities of the apprentices and their teachers (activity *interview*). The origami artists are immerged at the culinary school in order to teach origami to students and apprentices (activity *origami teaching*). Apprentices are immerged at the university in order to evaluate the students (activity *evaluate 1*), and students are immerged at the culinary school in order to evaluate the apprentices (activity *evaluate 2*). The last immersion concerns the certification where the professionals (chocolate world champion and origami professionals) are immerged at the culinary school to give the certification to the apprentices and the students.

3.3.4 Implementation

A preliminary immersive test is needed to ensure the complete acceptance by all actors. A design team made of six engineer students, a professional cook in pastry, two academic teachers and eight culinary teachers has been created. The objective was to test the feasibility of a collaborative and immersive strategy to design CBPM. Students had an immersive internship at the origami laboratory (Figure 5a) to understand the design philosophy of the artists and learn basic principles in origami. Some technical propositions have been then created (Rohmer et al., 2014b). Academic teachers and two origami artists had an immersive meeting at the culinary school in a classroom to understand the pedagogical strategy

(Figure 5b). An origami course was given to the culinary teachers to present origami principles and to obtain their technical feedback and approval for the project.


(a)


(b)

Figure 5. Origami immersion (a), culinary school immersion (b)

The positive feedback of the preliminary tests gave the starting signal of the (CO)² program. The first immersive activities will start in September 2015.

4 DISCUSSION

The paper proposes a framework for a better understanding of immersive systems by exploring new applications. The examples given in section 2 prove that immersive situations can accelerate the design process of products, and can give new knowledge to the designers. However, it should be remember that an immersive process can be confusing. The placement in a new environment can generate unwanted behavior if the process didn't take in advance the precaution to verify the acceptance by the actors. Moreover, the novelty of the environment can be too far from the expected idea of the actors, causing rejection and therefore a refusal to continue. As previously indicated, a preliminary test must be performed to ensure the acceptance. Conversely, the immersive system can generate additional values. In the blindness experiment (section 2.4.1), a social value appeared when the blind persons realized their performances by comparison to the difficulties encountered by those who had simulated. The same value appeared in the archery example (section 2.4.2). In the case of the (CO)² program, social value is expected through the immersion of engineer students with apprentices. Indeed, their educational level are different (level I and IV in the French educational system), but despite this difference, they have the same level of knowledge regarding the origami techniques. The skills of each other are needed to validate the products, they are socially equal.

In the theoretical part (sections 2.1 to 2.3), the immersive mode, transition and configuration space aims at the definition of referent immersive situations. The configuration space can be useful to understand the trajectory of actors and their changes during the transition of the immersive modes. According to the previous definitions, a configuration space can be represented by graph based methods. The vertices and the edges can respectively be represented by the actors and the workspaces with their attributes. Based on the interactions between actors and workspaces, a graph based modelling can also give information for a preliminary risk analysis by checking the failures modes of the actors and workspaces. A future paper will describe the methodology and the related analysis.

From an industrial point of view, immersive systems are synergistic systems. They are made of activities that mutualize or substitute actors. A mutualization activity means that a resource providing from a workspace is used with the resource belonging to another workspace, this situation is an immersive mode. Substitution means that a resource providing from a workspace is replaced by a resource belonging to another workspace, this situation is also an immersive mode. Then, the creation of immersive modes will consist in creating mutualization and substitution activities. However, designers should pay attention at the difficulties in creating synergies (i.e. immersive modes). In the (CO)² program, the pedagogical schedules of the culinary school and the university are different, the evaluation modes are different, the social situation of the students and the apprentices can be different, the role of the teachers in each institution is different. The similarities and differences must be carefully checked in advance in order to identify the expenses and their priorities in the implementation of the immersive program.

5 CONCLUSION

The paper proposes a framework aiming at the modelling of immersive systems dedicated to collaborative design processes. A typology of actors and workspaces is presented depending on their form and role. Based on this typology, the concepts of immersive mode, transition and configuration space are expressed. A case study involving academics and private stakeholders in the culinary sector is then presented to support the framework. The resulting immersive system highlights the importance of mutualization and substitution activities which have been generated from the immersive modes. Difficulties are also highlighted especially from a human viewpoint due the possible confusion and misunderstanding of the immersive process during its implementation. New investigations are already engaged to prove the efficiency of the immersive system of the case study by analysing the expected pedagogical gain and the resulting culinary products, it will be proposed in a next paper. The theoretical aspect will be also considered by developing graph based methods for the modelling of the configuration space of immersive systems.

REFERENCES

Brullot, S., Maillefert, M. (2008) Industrial Ecology in Practice: from flow analysis to coordination processes analysis, 14th Annual International Sustainable Development Research Conf., New Dehli, Sept. 21–23.

Chandra, Y., Leenders, M.A.A.M. (2012) User innovation and entrepreneurship in the virtual world: a study of Second Life residents, Technovation, No. 32, pp 464-476.

Fillatreau, P., Fourquet, J.-Y, Le Bolloc'h, R., Cailhol, S., Datas, A., Puel, B. (2013) Using virtual reality and 3D industrial numerical models for immersive interactive checklists, Computers in industry, No. 64, pp. 1253-1262.

In Vivo BVA (2014), http://www.invivo-bva.com/en/shopper_consumer_knowledge/ (11/22/2014)

Koutsabasis, P., Vosinakis, S., Malisova, K., Paparounas, N. (2012) On the value of virtual worlds for collaborative design, Design Studies, Vol. 33, No. 4, pp. 357-390.

Lee, J.F.K. (2009) ESL student teachers' perceptions of a short-term overseas immersion program, Teaching and teacher education, No. 25, pp. 1095-1104.

Lorenzo, C.-M., Sicilia, M.A., Sanchez, S. (2012) Studying the effectiveness of multi-user immersive environments for collaborative evaluation tasks, Computers & Education, No. 59, pp. 1361-1376.

Messinger, P.R., Stroulia, E., Lyons, K. (2008) A typology of virtual worlds: historical overview and future directions, Journal of virtual worlds research, Vol. 1, No. 1, pp. 1-18.

Rohmer, S., (2011) Tilting vehicle on skis, skids or wheels propelled by gravity and/or arm strength, France, WO 2011089350 A1.

Rohmer, S. Feng, H. (2013) Functional framework for the ecodesign of a sports medicine product, Advances in Modeling and Analysis C, Vol. 73, No. 3, pp. 134-147.

Rohmer, S., Mérat, A., Floderer, V., Copinet, A. (2014a) Crumpling feasibility of flexible paper sheets. Application to packaging in the food industry, SDM 2014, Cardiff, April 28-30, KES international.

Rohmer, S., Mérat, A., Floderer, V., Copinet, A. (2014b) Innovative design of culinary moulds based on crumpled papers, DESIGN 2014, Dubrovnik, May 19-22, Design Society.

Wang, X., Love, P.E.D., Kim, M.J., Wang, W. (2014) Mutual awareness in collaborative design: An Augmented Reality integrated telepresence system, Computers in industry, No. 65, pp. 314-324.

Warburton, S. (2009) Second Life in higher education: Assessing the potential for and the barriers to developing virtual worlds in learning and teaching, British Journal of Educational Technology, Vol. 40, No. 3, pp. 414-426.