Interactive Movement and Talk in Generating Meanings from Science

Zacharoula G. Smyrnaiou, and Chronis Kynigos

Abstract—In this paper we study language and full-body motion as an integral means through which students express thoughts and meanings when they interact with a set of collaborative digital games which we designed. The games rely on bodily expression based on the kinaesthetic recognition of the movement. Analyzing students' interactions as they played with a game we called "The Apples", we focused on their strategies expressed verbally in order to make sense of the scientific concepts embedded to the game. We also identified non-verbal strategies that enhanced the meaning generation process and were based on the use of different semiotic systems.

***Index Terms*—Meaning generation, students' strategies, body movement interaction, kinesthetic interface**

I. Introduction

In this paper we study language and full-body motion as an integral means through which students can express thoughts and meanings when they interact with a set of collaborative digital games we designed. These digital environments, which creatively involve interactions trough bodily movement, are set in an interactive educational gaming centre in Athens Greece, http://www.youtube.com/watch?v=d8AJwADKd90, called *Polymechanon*. The games rely on expression with body motion based on the kinaesthetic recognition (i.e. silhouette, location, gesture, bodily shadow, weight and position recognition) of the human body. The Polymechanon center includes eleven such collaborative games which embed scientific and mathematical concepts and are based on human control and interaction with digital and mechanical technologies. In designing these games, we wanted to move away from the individualistic and interactionist metaphors of kinect-like games and adopt a social collaborative paradigm for movement recognition games. We perceived verbal communication, body movement and the use of digital screen representations as semiotic systems used by children to communicate gaming parameters and explain the simulated phenomena on the screen.

Zacharoula Smyrnaiou is with the Educational Technology Lab, National and Kapodistrian University of Athens, Panepistimiopolis, 15784 Zografou, Greece (corresponding author to provide phone: 00302107277917; fax: 00302107277783; e-mail: zsmyrnaiou@ppp.uoa.gr).

Chronis Kynigos directs the Educational Technology Lab, National and Kapodistrian University of Athens, Panepistimiopolis, 15784 Zografou, Greece (corresponding author to provide phone: 00302107277526; fax: 00302107277783; e-mail: kynigos@ppp.uoa.gr).

We were interested in the role that this language would play in this multi-semiotic environment including body motion.

Within science education and mathematics, there have been attempts which focus on the consequences of a semiotic system on others or on the connectivity different semiotic systems. For example in the field of mathematics, Morgan put emphasis on one semiotic system, language, and in the ways in which it may serve as a crucial window for researchers in the processes of teaching, learning and doing mathematics> She focused particularly on situations where mathematical learning activities are conceived of as socially organized, that is, not only taking place within a social environment but structured by that environment [1]. On the other hand, Kynigos suggests that the ability to combine, interweave, and play with different connected representations (e.g. graphs, text, movement) supports the understanding of the underlying concepts and helps in their construction [2]. In the field of science, Smyrnaiou et al stress the importance of natural language for the understanding of scientific relations in [3]. Their research led them to suggest that if the student is not able to understand the transformations relationally, in natural language, s/he is unable to do it with formal systems. There have also been interesting approaches to address body, motion and senses as representational means with which humans express ideas and reasoning [4]. The question that we addressed in our study was how to employ such frameworks in synergy in order to approach the design of kinesthetic interfaces for learning, by addressing all these representational means for human expression in a holistic way.

Several experiments have been conducted on how children learn as they interact with tangible interfaces of learning environments for children [5], [6] in order to express mathematical and scientific meanings [7], [8]. There have also been interesting attempts to use gesture by students and kinesthetic interfaces [9], [10], and [11] when the manipulation and movement of tangible artifacts affects digital representations.

The distinctiveness in the learning game discussed here is that it requires students to collaborate while they move about in order to interact with the digital medium and play the game. In studying how students play this collaborative kinesthetic game, we were interested to understand what meanings they developed through full body-movement, language and embodied interaction with the games' digital representations and how these meanings related to the science meanings embedded in the game.

II. DESIGNING INTERACTIVE LEARNING ENVIRONMENTS BASED ON EMBODIED THEORY - A MULTI-DISCIPLINARY APPROACH

Following socio-cultural approaches, interactive environments do not exist in isolation to the real-world but rather belong within a context where actors use common-sense practices to produce, analyze and make sense of one another's actions. "Situated actions" unfold in situ where participants act and interact within an environment [12]. It draws attention to the character of an informal interaction of people with technology in social settings rather than focusing only on the cognitive processes. Practice [13] is something more than doing, it is a process during which one investigates, acquires experience from the world. Collective practice relates to the shared experience and embodied interactions of individuals within a community of a common interest [14].

Following a psychological perspective, activity is a cycle that begins from the brain and, through the body and the world, returns back constituting knowledge. The power of cultural structure can lead to the transformation of the problem solving activity [15]. The way that a group of learners interact with each other and with the technology could lead to new forms of gaming and learning activities which the designers have not anticipated.

Embodied interactions [4] in technological environments, where metaphor theory [16] is put into use, associate actions of the entire body (as inputs) with auditory replies (as outputs). Results have shown that embodied interactions in an auditory environment improve the ability of using the environment for both adults and children [17]. However, other factors, including discovery, perception of feedback and duplicity of structural isomorphism can mediate for these benefits.

The subject area of mathematics and science affects the design of interactions, behaviors of digital artifacts and representations. Subject-oriented problems can be embedded in digital games involving connected representations and different kinds of interactions. For example a key element of mathematical thinking is the ability to abstract and generalize. Dynamic manipulation of representations of digital artifacts allows students to directly tinker with generalized objects rather than instances of such objects. Mathematical manipulations [18] have now become popular tools in mathematics since they offer important and creative learning opportunities as stand-alone or embodied in other computing media.

Gaming experiences in virtual multi-user gaming environments (such as Second Life and Active Worlds), as well as online mass games (such as World of Warcraft) provide opportunities to study users' experience with technologies from innovative points of view [2], [19]. The task of genuine integration between game-play and the learning objectives and outcomes is a key challenge for using games effectively [20].

The idea transcending the Polymechanon games has been to put into practice these theoretical principles in order to form a test-bed for exploring and playing with digital extensions to realistic games where representations and interactions embedded scientific concepts and powerful ideas. In the remaining sections of this paper we describe the study that we carried out to explore the kind of meaning sgenerated by the students during play with one of these games.

The digital game in question is an extension of a real ball game played in Greece in the old days where players throw a ball trying to get it to touch their opponents while they try to avoid this by moving out of the way either by moving their legs, jumping or body twisting. The extension to this game is through the digital representations, the bodily interaction and the computer in the role of the ball thrower.

III. A GAME CALLED 'THE APPLES'

We chose to focus on one of the games installed in the Polymechanon embedding concepts from newtonian physics and mathematics and providing graphical and body movement semiotic systems for interaction with the game. The 'Apples' game is one of four full-body games based on shadow recognition and one of two integrating concepts from science and mathematics.

In this game, the players try to avoid the graphical shapes they see on the big screen coming from the right hand corner of the screen towards their body shape which is also depicted on the screen. The way to do this is to either duck or jump at the right moment (figure 1). The game however is not a classic wii-style game where one individual interacts with the computer or two take turns. Three players try to avoid the objects in sync, if an object 'touches' one player they all miss a point. The players need to thus negotiate their positions, their strategy, maybe devise a management structure (e.g. one player calls out to the others what's coming or what to do).

Fig. 1. The players try to avoid the shapes moving at different heights.

Each shape moves at a different height. The players need to estimate the speed and position of shapes so as not to be 'hit' digitally. If the shape is at a medium height a decision has to be made on the spot whether to duck or jump.

In this collaborative game, the students have to use their whole body and not just their hands in order to win. Embodied interaction and verbal communication among them are vital. The strategies they will adopt play a decisive role. The concepts of time and height (displacement) in such an activity may constitute a matter of consideration for the students.

IV. Methodology

This preliminary evaluation study was performed at the Polymechanon with secondary school students, spread across the various exhibits in groups. The age of the participating students in the research was 12-15 (junior high school / middle school students). The total number of students who participated in the research and more specifically in the “Apples’ game was 47. All students alternated in playing all of the full-body games in groups, while a team of three researchers participated in each data collection session, using video and audio recorders. Background data such as students’ worksheets and researchers’ observational notes was also collected and all recordings were analyzed verbatim. In addition, post-task interviews were conducted with all participants. No instructions were given to the players before or during their game playing experience.

V. Data analysis

Even though all students played with all of the games, for the purpose of this study we limited our observations to students' playing, interactions, and responses concerning the “Apples” game. The questions asked concerned the strategies students developed and used implicitly or explicitly, their understanding of the embedded scientific concepts, and the verbal interactions among them. The students’ answers were recorded according to sex, age, school type and school year. In analyzing the data, we first looked for instances where meaning generation processes seemed to emerge as the students interacted with the game. In addition, we paid attention to how they acted as members of a group and interacted with their class-mates and with the motion interface. Specifically, we looked at excerpts of students’ play with the mobile interface in which they try to make sense of how the time, height, displacement and other scientific concepts affected their strategies.

VI. Students’ strategies and meaning generation processes

After the introductory activity in which the main point was to get familiar with the “Apples” game the college students played in teams. We observed that the longer they played the more their verbal interactions changed from action-centered to concept-centered.

The common strategies to avoid the bricks, as expressed verbally by the students during a post-task interview (table 1), are the following: “they jumped as high as they could”, “they focused on the exact moment when they had to make the movement to avoid an object”, “they focused on the height at which the bricks moved”, “they estimated the time from the moment each brick appeared” or they gave no answer. From the students’ answers regarding the strategies they implemented, we can come to direct or indirect conclusions related to the way they perceived the ‘hidden’ concepts.

TABLE I
STRATEGIES MOST COMMONLY IMPLEMENTED IN THE GAME “APPLES”

Strategies (expressed verbally)	%
We jumped as high as possible/ducked as low as possible	34,48
We focused on the height that the bricks moved.	16,09
We estimated the time from the instant each brick appeared.	6,89
We estimated how much time we needed to respond.	11,49
We focused on the instant we had to make the escape movement.	21,83
Other strategy	0,00
No answer	9,19

From the video recording, we also observed other more implicit strategies. Specifically, students moved outside the game area to avoid being hit by the brick and returned to continue, they moved as far left as possible to increase the time of the brick movement and thus have more time to think the type of movement they would make, they lay down on the floor to squeeze underneath the bricks, they formed a triangular shape, they move outside-inside, they accelerated, they did not collaborate at all, they did dance movements or scissor like leg movements, they stood very close to or very far from the interactive interface, they mimicked the player next to them disregarding the bricks, which usually led to a non-timely response, they imposed on each other when and what to do, e.g. grabbed the other player’s hand and made him/her jump, they warned the rest when to jump and when to duck and “=of not surprisingly they larked around finding the game too challenging. These strategies influenced the meaning generation processes. The students depicted the kind of movement made by them as uniform (36,17%), no uniform (29,78%), or (21,27%) some other type of movement.

For example, they explained that as players, they moved around constantly since they moved 'continuously and everywhere', in a like zig –zag fashion or “other times to the front, other times to the back” or “an ‘out’ movement” when they moved outside the game area to avoid being hit by the brick. They explained that the bricks made a changing movement because “they moved continuously and everywhere”, “other times high, other times low” and that their “speed changed”. We assume that behind these strategies there is scientific content hidden to be found which is connected to the embodied interaction. If not in all, at least in some strategies.

VII. Conclusion

The purpose of the study described here was to explore collaborative embodied interaction with connected representations as an integral part of expressing scientific meaning in the use of full-body motion and language. The 12-15 years old we observed in these collaborative activities with the “Apples” game seemed to perceive full body motion as a natural way to interact with the games without turning their attention away from the concepts and the need to negotiate about them. Analysing the students’ interactions as they played with the game, we focused on their strategies expressed verbally in order to make sense of the scientific concepts embedded to the game. The verbally expressed strategies are revisited again and again as the students play and for some of them the rationale changed from action-centered to concept-centered the longer they played. However, it seems that there were many implicit strategies that enhance meaning generation processes and were based on different semiotic systems related to embodied or collaborative experience as the students played in order to avoid the shapes they saw on the big interactive interface. These strategies seemed to feed students’ meaning processes, as the students played and observed the outcome of their strategies and reshaped their understandings accordingly.

The study has certain limitations that need to be taken into account when considering its contribution to design. It points to the need for a lot more research into how pedagogical and interaction design techniques can enhance the probability that students may draw added value in understanding the concepts themselves. A seamless integration of body movement and verbal communication as key representation registers added to the screen graphics is a task in itself. In our designs we considered inserting embodied learning in a context where interaction and connectivity with other semiotic systems may give it some added value in generating understandings of the concepts at hand. Our study shows that this issue has potential enough to be studied further.

In this sense, it is only the beginning in a series of evaluation efforts with players of different ages and games of different kinds. It is also a beginning in an exploratory process for identifying the kinds of semiotic systems needed for students and educators and the types of design aids for interaction designers seeking to develop digital games relying on tangible expression based on the kinesthetic recognition of the human body.

Acknowledgment

We thank 'Feedtank' for allowing us to shape and re-design their games with educational principles.

References

[1] C. Morgan, “What does social semiotics have to offer mathematics education research?”, *Educational Studies in Mathematics*, vol. 61, no 1, pp. 219-245, 2006.

[2] C. Kynigos, “Half-Baked Logo Microworlds as Boundary Objects in Integrated Design”, Informatics in Education, vol. 6, no 2, pp. 1–24, *Institute of Mathematics and Informatics*, Vilnius, 2007.

[3] Z. Smyrnaiou, and A. Weil-Barais, “Évaluation cognitive d’un logiciel de modélisation auprès d’élèves de college”, *Didaskalia*, vol. 27, pp. 133-149, 2005.

[4] G. Lakoff, and R. Núñez, *Where Mathematics comes from*, New York: Basic Books, 2000.

[5] A. Antle, C. Kynigos, L. Lyons, P. Marshall, T. Moher, and M. Roussou, “Manifesting embodiment: Designer’s Variations on a Theme”, In *Proc. of CSCL* (Rhodes, Greece), Panel, pp. 15-17, 2009.

[6] P. Marshall, “Do tangible interfaces enhance learning?”, Paper presented at the 2007 *Proc. of the 1st Int. Conf. on Tangible and embedded interaction*, Baton Rouge, Louisiana.

[7] C. Kynigos, Z. Smyrnaiou, and M. Roussou, “Exploring the generation of meanings in mathematics and science with collaborative full-body games”, in 2010 Proc. of the *9th Int. Conf. on Interaction Design and Children*, Barcelona, Spain, pp. 222-225.

[8] S. Bakker, A.N. Antle, and E. van den Hoven, “Identifying embodied metaphors in children’s sound-action mappings”, in *2009 Proc. of Int. Design for Children* (IDC’09), ACM Press (Como, Italy), pp. 140-149.

[9] A. N. Antle, “The CTI framework: informing the design of tangible systems for children”, Paper presented at the *2007 Proc. of the 1st Int. Conf. on Tangible and embedded interaction*, Baton Rouge, Louisiana.

[10] P. Marshall, S. Price, and Y. Rogers, “Conceptualising tangibles to support learning”, in 2003 *Proc. of the 2nd Int. Conf. on Interaction Design and Children* (Preston, England, June, 2003), IDC’03, ACM Press, New York, NY, pp. 101-109.

[11] C. O’Malley, and D. Stanton-Fraser, “Literature review in learning with tangible technologies”, *Futurelab series*, report 12, 2004.

[12] L. A. Suchman, Plans and situated actions: the problem of human-machine communication, Cambridge, UK: Cambridge University Press, 1987.

[13] P. Dourish, *Where the Action Is: the foundations of Embodied Interaction*, Cambridge: Massachusetts Institute of Technology, 2001.

[14] E. Wenger, Communities of practice: learning, meaning and identity, Cambridge: Cambridge University Press, 1997.

[15] M. Wheeler, and A. Clark, *Culture, embodiment and genes: unravelling the triple helix*, Philosophical Transactions of the Royal Society B 363, [1509], 2008.

[16] G. Lakoff, and M. Johnson, *Metaphors We Live By*, Chicago Press, Chicago, IL, USA, 1980.

[17] A.N. Antle, G. Corness, and M. Droumeva, “What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments”, *Interacting with Computers: Special Issue on Enactive Interfaces*, vol. 21, no 1-2, pp. 66-75, 2009.

[18] M. Eisenberg, and J. diBiase, “Mathematical Manipulatives as Designed Artifacts: the Cognitive, Affective, and Technological Dimensions”, in *1996 Proc. of the Int. Conf. on the Learning Sciences*, Chicago, 44-51.

[19] C. Kynigos, “Black-and-white-box perspectives to distributed control and constructionism in learning with robotics”, *Workshop Proc. of SIMPAR*, *Intl. Conf. on Simulation, Modeling and Programming for Autonomous Robots*, Venice (Italy), pp. 1-9, 2008.

[20] K. Facer, R. Joiner, D. Stanton, J. Reid, R. Hull, and D. Kirk, “Savannah: mobile gaming and learning”, *J. Computer Assisted Learning*, vol. 20, pp. 399–409, 2004.

Zacharoula Smyrnaiou is Lecturer in “Didactic Science” and Researcher in Educational Technology Lab (ETL, School of Philosophy, University of Athens, http://etl.ppp.uoa.gr). In the recent years, her research interests and publications concern the teaching of science using new information technologies, the integration of computers in education, the conception and the development of educational software and the Educational Sciences.

Chronis Kynigos is the Director of Educational Technology Lab (ETL, School of Philosophy, University of Athens, http://etl.ppp.uoa.gr) and a Professor of Educational Technology and Mathematics Education. In the past 15 years, he has led the pedagogical design of educational digital media and employed them in research involving a) aspects of designing and generating socio-constructivist learning environments in the classroom (emphasis on mathematics), b) design and implementation of innovative teacher education methods and c) the design and implementation of methods to infuse innovation in the educational system.