WHEN A CLASSROOM IS NOT JUST A CLASSROOM: BUILDING DIGITAL PLAYGROUNDS IN THE CLASSROOM

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ABSTRACT
In the context of classroom, it is possible to create a playground with digital technology beneficial for learning in spite of rising enthusiasm in incorporating educational games in classroom. This paper is an essay to describe a learning playground called Digital Learning Playground (DLP). It is essentially an application of digital technology to build a Mixed Reality environment with game-based-learning-like ingredient for classroom context. A learning theory that could be used to describe the learning process is that of experiential learning by Kolb. Meanwhile, Total Scenario Response (TSR) can be used for its learning design. Although the experiment was applied in the context of learning English, it may open a possibility to extend for the purpose of learning other subjects, such as Math.
Keywords: Digital Learning Playground (DLP), Total Scenario Response (TSR), experiential learning theory, game-based learning.

INTRODUCTION
Recently, there has been growing interest in the application of new digital technology to improve playing, learning and education. For example, Seitinger, Sylvan, Zuckerman, Popovic, and Zuckerman (2006) reported a design and testing experience of their prototype work on interactive pathway for kid outdoor playground. As another example, Intelligent Playgrounds (Sturm, Bekker, Groenendaal, Wesselink, & Eggen, 2008) were proposed to enhance playground experience with advanced technologies as an effort to overcome the impact of computer games and televisions on reduced social interaction due to children's time spent in gaming and television viewing, and children's health because of reduced physical movement. An example in e-learning is the use of animated pedagogical agent as an emphatic avatar to emotionally encourage students to keep on their learning (Chen, Lee, et al., 2011). In the context of classroom, it is possible to create a playground with digital technology beneficial for learning in spite of rising enthusiasm in incorporating educational games in classroom. Educational games in classroom may be classified based on the use of devices into three types as follows:

1. Without using any IT devices: This type uses a minimum of teaching aids, and the aids sometimes are the lightest and cheapest. This method has been widely adopted by classroom teachers, and most classmates can be involved in the game at the same time. Or some are playing while others are learning through observation and imitation. However, these simplest teaching aids constrain the complexity and variety of games; consequently affect students' deep of learning and chances of practicing their learned knowledge.
2. Using vertical screen as TV games or computer games: In classroom, the screen can be big enough for every student watching it while using a project. However, only few students can play the game with or without teacher's instructions. Rest of the classmates can only observe aside. Teachers could not allow more students to be involved in the playing at the same time. Involvement and learning effect on those observers might be deficient.
3. Using horizontal table as board games: Using a horizontal table as a playground is the common feature of

these games. More students can sit around the table and compete excitingly. Compared to the first type (without using any IT devices), the plot and some game aids on the table could offer higher complexity and extensibility of learning results. Compared to the second type (using vertical screen), the horizontal table can gather students around and involves them in game playing.

Vertical screen and horizontal table however have different strengths. If providing avatars to communicate with students, using vertical screen is recommended. If requiring group discussion or movement of something concrete on the game plot, a horizontal table should be adopted. Similarly, if we want to create an experiential learning (Kolb, 1984) environment, a vertical screen synchronized with a horizontal table might be of great help to students involvement in situation and learning.

Compared to conventional game-based learning for classroom use, DLP can provide an alternative way. Although game-based learning is believed as capable of making an engaging learning environment (Garris, Ahlers, & Driskell, 2002), it is not always convenient to use in classrooms where teachers oftentimes need to directly guide their students during learning process. Thus this paper offers a design that can make game-based learning be put into classrooms, i.e., how to make classrooms become learning playgrounds. Total Scenario Response (TSR) is devised to design learning activities in the digital playground where all of its game scripts proceed by using the learning materials. When the learners apply the knowledge required in the scripts, they can experience its effect. As a learning place, DLP can involve teachers and students in the learning playground activities while the teachers can act as learning guides and the learners can experience the effect of the knowledge in the playground.

The structure of the paper is as follows. Next section describes the improvements of classrooms followed by a section on theoretical principle behind DLP, the experiential learning. Finally, before discussion and conclusion section, the connection between DLP and Total Scenario Response is explained.

IMPROVEMENTS OF CLASSROOMS WITH DLP

Classrooms are almost always the major learning environments for students. However, in the past, learning in classroom does not change too much. Even so many technologies have been introduced into classroom (Westera, 2010), such as whiteboards, overhead projects, and instructional television, most students still sit in line and learn from teachers' lectures. Recently, the design-based research approach (Wang & Hannafin, 2005) and rapid development of technology make the revolutionary change of the learning in classrooms become possible.

Traditionally, when students were prepared for industrial labors, classroom learning was instructionism. Later finding from cognitive sciences, deep learning has gradually been applied in classrooms (Sawyer, 2006, pp. 1–16). Deep learning requires not merely transfer of knowledge from the teacher to students, but it is dynamic interaction and transaction among the teacher, knowledge and the students. Change also happen in computer and technology use and innovation for learning, from the role of expert to deliver knowledge into a facilitator to give experience to enable deep learning. And according to Kolb in Zull (2004), deep learning can be attained through an integration and progression of experiential learning cycle: experiencing, reflecting, abstracting (thinking), and active testing (acting). A classroom moves from static to more dynamic nature.

Recent technological support for dynamic interaction can be found in touch technologies, for example, tablet PC, touch screen monitors, and interactive whiteboards. A notion of engagement emerges due to touching activities by a teacher or students made possible from this innovation. With the tablet PC, students can dynamically interact with the digital learning content, and then participate by touching the screen for hands-on practice. In digital board game learning design based on the DLP, SMART board for easy objects manipulation by touching was also used (Chen, Wu, & Chen, 2011).

Another tool to enhance classroom learning is simulation, especially computer simulation. An example in engineering education is a network growth simulator program (SONG) that was shown to increase understanding of the subject matter and improve higher-order thinking skills of the students (Chen & Levinson, 2006). When real experiment cannot be done in real physical settings due to its size that is too small or too big, its dangerous nature, or its being invisible, or its being too expensive, oftentimes simulations can help (Steinberg, 2000). With simulation as an experiential knowledge generator (Ören, 2011), learners can learn by experiencing, through doing, interacting, and thus engaging their motivation to learn (Chen & Levinson, 2006). While a simulation is usually done with a computer with standard I/O facilities, such as a keyboard, a mouse, and an LCD Monitor, there are also other growing interests in extending simulation effect and capabilities by using other ways to improve learning effect. The choice of 2-D or 3-D visualization for simulation interface may

facilitate students to create meaning, to interpret, and to express that influence their learning. Limniou, Roberts, and Papadopoulos (2008), for example, visualized chemical phenomena designed for CAVE^{TM} that could increase student's learning interest and motivation. Moreover, when Mixed Reality (MR) technology is applied to education and used in a classroom, an idea to create near authentic learning environment may be realized (Chang, Lee, Wang, & Chen, 2010). Knowledge construction is accommodated by this MR-based learning environment because the environment may support constructivism and experiential learning, social/collaborative learning, presence, immersion, and interactivity (Liu, Cheok, Mei-Ling, & Theng, 2007). The enhancement becomes a kind of a simulation with extra benefits; and a term *simulation++* may be coined to this, which is an MR technology to simulate an authentic learning environment to produce (near) authentic learning effects. In another case of MR use is a work by Schaf, Müller, Pereira, and Bruns (2008) where MR is designed for learning environment of remote labs and distributed workspaces. In this setting, collaborative learning is achieved with reduced cost because no duplication in real hardware.

When robot technology is also included, some possibilities occur, for example, collaborative learning can be realized using robots. Experiments or demonstration in physics, such as lesson in motion, can be done with robots specifically designed for this. Collaboration might be facilitated due to the tangible nature of robots, in which a shared space for collaborative transaction can be designed. (Marshall, 2007). Moreover, direct interaction by seeing each other's gaze is possible, thus speeds up the understanding of meaning communication. In this case, collaboration, as opposed to independent learning, is indeed one characteristic in meaningful learning (Jonassen, Howland, Marra, & Crismond, 2007).

While robots become increasingly more accessible, they have also been incorporated into the design of DLP. As in Chang, Lee, Chao, Wang, and Chen (2010), robots can be used to play some roles in the classroom, and it was analyzed that some characteristics of robots match with some instructional goals. These robot characteristics include repeatability, flexibility, shareability and preservability, existence with human-like, body movement, interaction, and suspension humanity; each or some of these can be mapped into one or some instructional goals, such as to gain attention, to recall prerequisites, to present objectives, to present new content, to support visual examples, to elicit student response, to provide feedback, to enhance retention and transfer, or to assess performance. It was also identified that robots plays three roles in instruction: learning/teaching tools, teacher's assistant, and learning companions/pets (Chang, Lee, Chao, et al., 2010). In DLP, these robots can also be used as partner/delegation of a team. The benefits of robot as physical and tangible interface were explored. Authentic learning is more supported with robots than virtual characters due to learners' preference in interacting with robots (Chang, Lee, Wang, et al., 2010).

Advances in new digital technology indeed help in realizing authentic learning environment because more complex interactions and thus learning experiences can now be designed (Reiser, 2001). However, as can be seen in Jurassic Park movie, learning experientially a dinosaur in a Jurassic Park can be dangerous because a real complex adaptive system like a dinosaur may behave unpredictably (Katerndahl, 2009). In this case, to save students from any possibility of unwanted risks, a simulated environment may be needed. An effort to do this is by creating a Digital Learning Playground (DLP). Besides as a simulated environment, DLP has been designed to investigate the possibility of creating an authentic learning environment in the classroom (Wang et al., 2010). In a DLP, a "dinosaur" (everything not possible to learn directly and experientially) may be safely brought into a classroom and learned. While meeting the experiential learning requirements, the DLP can be a safe place for a teacher to teach and students to learn. DLP is a kind of enhancement or transformation for a classroom. It integrates and merges various components to provide an experiential near authentic learning environment.

The DLP has somehow been capable of moving Jurassic park into a classroom with the "dinosaurs" are readily provided to learn simultaneously by the teachers and students, in which case the dinosaurs represent real world that oftentimes complex, dangerous, or impossible to learn experientially and in situated manner. The DLP provides *simulation++* learning environment by using target knowledge in context, with a mission to be completed by students, and a set of learning events to facilitate performing actions that are required by target knowledge.

In DLP, the perspective is different from the one used in game-based learning, in that DLP starts from fun learning first point of view. The point is to have fun while learning instead of to learn while having fun such as in game based learning, and this is possible due to digital technologies. In DLP, digital technologies are used to build a near authentic learning environment in the classroom. Digital technologies, as predicted by Moore's Law ("Moore's law - Wikipedia, the free encyclopedia," n.d.), continue to grow, improve, and become increasingly more available to everyone, including for every classroom. E-books, Kinect, voice and video recognition, pervasive computing, mixed reality, augmented reality, virtual reality, etc., will become available in classrooms

soon. As an illustration, a similar program, called One Laptop Per Child (OLPC), has been in operation since 2007 (http://one.laptop.org/). It is envisioned that game-based learning will become digital playground based learning played in classrooms.

In DLP, the word "learning" means putting learning content into the environment in which the playground is set to convey the context for knowledge while activities/tasks are designed to use target knowledge as the commands (Chang, Lee, Wang, et al., 2010). The word "play" requires that the learning activities should be fun and engaging. Finally, "ground" indicates that the environment is created to let the students be involved in or stood on it.

While in game based learning, learning effect is tried to be obtained by students' playing game. Thus game-based learning is a kind of "a medicine pill coated with sugar", whereas DLP by design may represent "delicious and nutritious food beneficial for health and curing illnesses" prepared from the beginning. However, as in Kiili (2005), DLP shares the characteristics of the experiential gaming model where there are three components that need to be available: immediate feedback, obvious goals and suitable challenges. These are what play or game characteristics in order to be fun, including also fantasy, competition (no user elimination), challenge, control/command (immediate response), curiosity, randomness (surprise), recognition, and users' involvement and engagement (Malone, 1980).

To conclude the section, advances in technology from time to time has influence on teaching and learning activities in classrooms. As another application of current technology, the DLP is designed to become a platform for classrooms. Required equipments for the DLP have already been available in classrooms. Thus the technology is affordable and it may provide a near authentic learning environment and experiences to conventional classrooms. Moreover, as suggested by Jonassen et al. (2007, pp. 2–5), learning with technology in order to become meaningful learning, required 4 characteristics – active, constructive, cooperative, authentic, and intentional – may be fulfilled in DLP.

THE DESIGN METHOD OF DLP
In following sections, the method for designing and developing DLT is addressed and several DLP implementations that are designed according to this method are introduced.

Total Scenario Response (TSR) design method
When Confucius (ca 450 BC) says "Tell me and I will forget; show me and I may remember; involve me and I will understand," this now coincides with the essence of experiential learning theory (Kolb, 1984) which is based on the constructivism philosophy. The definition of learning in experiential learning theory is "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). Thus an efficient and long-lasting form of learning is to involve the learners by creating a meaningful learning experience. Learning is the process whereby knowledge is created by the transformation of experience.

Figure 1 is a review of the four stage process model of experiential learning cycle by Kolb (1984). The learners go through a circular process from Concrete Experience: act, reflect, conceptualize, apply, and go back to act. The learners act by starting with concrete experience, followed by reflection, followed by abstraction or generalization, and lead to application to more concrete experiences. And this cycle goes repeatedly. Vertical line as perception continuum represents experience grasping mode – Concrete Experience (CE) and Abstract Conceptualization (AC), whereas horizontal line as processing continuum represents experience transforming mode – Reflective Observation (RO) and Active Experimentation (AE). The learning process in the model happens in clock-wise direction.
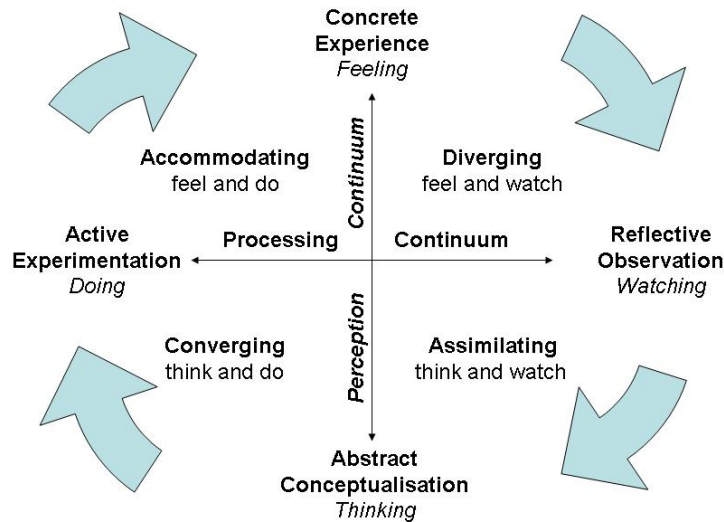
Figure 1: Four-stage of Kolb Experiential Learning Cycle (Kolb, 1984)

In terms of design of learning activities, the DLP can use this model of four-stage learning cycle where learners' direct experiences and reflections on learning are considered as important. Each learning activity is derived into three components: act, respond, and reflect, as follows: (1) Act – Learning contents are converted into robot commands by which students can communicate with the robot and the stage; (2) Respond – every command accepted by the system from the student is immediately responded in multimedia display; (3) Reflect – by experiencing the command and immediate response, students can reflect the situated knowledge via system feedback and they can decide whether they use knowledge correctly or not. This leads to Total Scenario Response (TSR) design method.

TSR method could be used as the basis for learning design in DLP. It is named after Total Physical Response (TPR) method previously developed by Asher (1969) for second language learning. The principle of TPR is "to have the students listen to a command in a foreign language and immediately obey with a physical action." In other words, students respond to commands that require physical movement. Analogue to this, TSR requires that the scenario (learning context environment) respond to the commands of the learners. As a result, learners should readily understand from the response of the scenario. In TSR, the following principles (Table 1) could be applied

Table 1: Principles of Total Scenario Response (TSR) Design Method

Component	Principles
Total	Total means complete to include the following: • The effect of the command (based on the knowledge) from learners should be responded in the Scenario so that the learners understand the effect of the knowledge • *All* knowledge to be learnt is transformed into commands • Immediate responses are provided and affordance of the response is acceptable
Scenario	• The interactive contextual environment is built in the classroom by using digital technologies • Scenario can have proper and understandable response of the effect of the knowledge • Scenario contains a mission that can be broken down into learning activities, tasks, or commands
Response	• The commands from the learners should be based on the knowledge to be learnt. • Each learning activity consists of input and output where the input is a knowledge command and the output is the effect or representation of the knowledge • Output is immediately shown as a response to input

The TSR in practice is derived further into the following tasks for teachers and students: (1) Teachers: They do

knowledge orientation/demonstration to teach how to use the DLP and how to apply knowledge by interacting with the system in the environment to accomplish learning tasks; in which case, commands represent knowledge. They demonstrate how to interact with DLP to construct knowledge. (2) Learners: They attend to orientation and demonstration from teachers, experience knowledge application, do reflective observation, for example, by watching others actions (knowledge observation), discuss practical experience of other students, and do active experimentation. Thus the DLP facilitate demonstration/orientation, application, and observation of knowledge.

As previously mentioned that Act-Respond-Reflect cycle is devised for experiential learning in DLP, in order to be able to do these cycle for classroom learning, the DLP provides appropriate context for experiencing knowledge (microworld) and tasks to let student use knowledge to move towards to the goals of authentic tasks. Context may be derived from Scenario component whereas tasks from Total and Response components (Table 1). Therefore, Total Scenario Response is proposed to design a DLP for students to recognize problems, use knowledge to solve them, and experience the effect of knowledge.

The DLP designed based on TSR
Figure 2 shows the basic form of DLP realization with TSR design method. In this arrangement of dramatic stage metaphor, the vertical screen of DLP presents situational scenarios for designing the learning content and the table forms a learning space that classroom teachers and students can stand around and perform tasks. Digitalization of a dramatic stage into a DLP gives benefit that it can provide immediate responses for the actions learners did so they can learn by experiencing. This is not always the case in a real context: upon doing one thing based on learners' knowledge, the learners may not immediately get reaction from the environment for their action. Figure 3 represents another example of DLP.
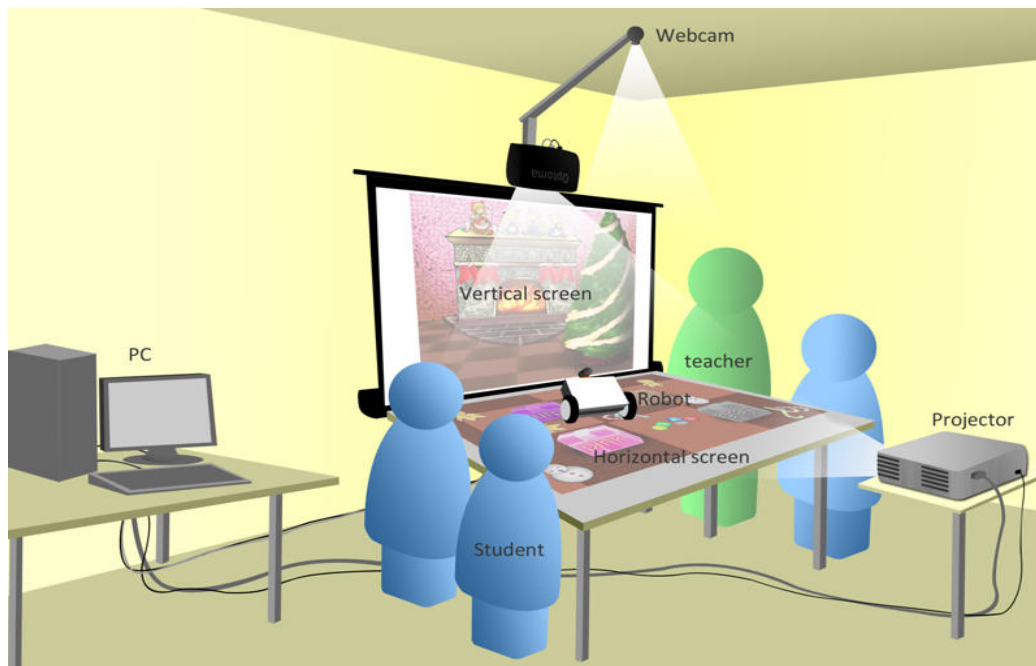

Figure 2: Basic Arrangement of DLP realization with TSR Design Method

Figure 3: RoboStage: Another Example of DLP to Realize Playground Based Learning (Chang, Lee, Wang, et al., 2010)

To learn experientially in DLP, a situation comprising of learning context and mission for experimenting the target knowledge is created. The mission can be broken down into learning activities that can be further broken down into tasks and then commands (Table 1). The learning context may be represented in many ways: It can be a contextual environment designed according to learning subject where technology like Kinect and tangible interaction can be used. It can be a real field where students interact in the context as if they were in real environment. It can also be a simulated or emulated (mixed reality) environment. Learning activities then can be designed based on knowledge and knowledge map, in which learners can do activities and knowledge experiment.

The situation created in DLP provides situated learning, learning that requires context to apply the knowledge. It is when situated learning is combined with play elements that it may become a learning playground. To create learning context representing the situation needs to design contextual environment based on learning subject. The environment can be a real field or a simulated or emulated (mixed reality) environment. Learning activities are then designed based on the knowledge or knowledge map, which could be activities or knowledge experiments. Finally, tasks or mission needs to be found so the activities will be oriented to this. These three elements – learning context, learning activities, and task or mission – build a learning playground environment.
In the environment, learners will interact with contextual field and this is not a new thing but this interaction has gone through an evolution in some phases. The first phase is Windows Icon Menus Pointers (WIMP), which is later called Graphical User Interface (GUI), when windows, icon, menus, and pointers kind of interaction are used. The second phase is delegation or virtual partner such as by using robots or avatars. The third phase is human emergent in the field with natural interaction (via body movement, hand gesture, and voice) or tangible interfaces. The DLP anticipates this third phase of interaction because tangible things like robots are believed to give more benefits than virtual agents (Chang, Lee, Wang, et al., 2010). Wainer, Feil-Seifer, Shell, and Mataric (2007) found that an embodied robot was more appealing and perceptive of the world than non-embodied robots. Moreover, the embodied robot was seen as most helpful, watchful, and enjoyable when compared to a remote tele-present robot and a simulated robot.

To end this section, our works based on the DLP have been related to robot, board game, and users' direct involvement with interactive card (Jiang, Chen, Wu, & Lee, 2011). In the beginning before the digital stage was built, the research examined the educational use of a robot in a classroom, e.g. Chang et al. (2010), in which the

classroom setting was used as the context. Later research, a digital stage, as a stage based learning game, was built for the robot (Wang et al., 2010). Another development adopted board game in horizontal stage with vertical screen was used for simulative context (Chen, Wu, & Chen, 2011). Another experiment using the DLP, a robot functioning as a learning partner/companion was shown to engage students in learning English (Chen, Chi, Huang, Fan, & Wu, 2011).

DISCUSSION AND CONCLUSION

A digital playground, called Digital learning playground, as a platform is aimed at building a near real context field that the knowledge is to be used to achieve mission and complete tasks. With this platform, experimenting with and making explicit of the process of authentic learning, learning by doing, or situated learning by using technology is possible.

The Digital Learning Playground involving robot has been created to help students learn in authentic environment. Currently, a modified version of the playground utilizes digital board game in its tabletop featuring touch enabled pad in which the students learning are also engaged and satisfied by means of a gaming flow (Chen, Wu, & Chen, 2011). Another finding (Chang, Lee, Wang, et al., 2010) confirms that robot character is better than virtual character in terms of authenticity, engagement, and motivation; thus this may increase learning performance. These hopefully may motivate future researches in the use of similar computerized tangible technological products for learning. In other words, this may inspire other educational researchers to innovate further so that learners can learn by doing and playing.

Viewed from the context of learning researches and innovations, robot itself has potential to be used as an instructional tool in the context of classroom setting due to its beneficial characteristics in supporting instructional goals (Chang, Lee, Chao, et al., 2010). Furthermore, by including a robot on the tabletop in DLP context, as compared to using virtual character, the finding suggests that learners' preference to interact with is robot (Chang, Lee, Wang, et al., 2010). This implies that physical things have higher potential to engage and to support authentic and possibly experiential learning due to its higher sense of being and reality. Although the experiment was applied in the context of learning English, it may open a possibility to extend for the purpose of learning other subjects, such as Math.In another context, with current existing technology support, affordable near authentic learning environment can be brought to classrooms. However, this may have implication that teachers may find it difficult to prepare lessons with DLP by themselves until a mechanism such as a "DLP authoring tool" is developed or invented in the future. The tool is supposed to be easy to learn and to use by the teacher. Alternatively, there might be an educational company developing and providing a complete set of DLP hardware and teaching-ware available for every subject or lesson.

Future development of the platform will be working toward constructing natural tangible interaction for the learners and trying to consolidate theory base of Digital Learning Playground and Total Scenario Response method. Besides, as previously mentioned, another possibility is to investigate the application of the platform to different courses.

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REFERENCES
Asher, J. J. (1969). The Total Physical Response Approach to Second Language Learning. *The Modern Language Journal*, *53*(1), 3-17.

Chang, C.-W., Lee, J.-H., Chao, P.-Y., Wang, C.-Y., & Chen, G.-D. (2010). Exploring the possibility of using humanoid robots as instructional tools for teaching a second language in primary school. *Educational Technology & Society*, *13*(2), 13-24.

Chang, C.-W., Lee, J.-H., Wang, C.-Y., & Chen, G.-D. (2010). Improving the authentic learning experience by integrating robots into the mixed-reality environment. *Computers & Education*, *55*(4), 1572-1578. doi:16/j.compedu.2010.06.023

Chen, G.-D., Chi, Y.-L., Huang, C.-W., Fan, C.-Y., & Wu, C.-J. (2011). Design a Partner Robot with Emotions in the Mixed Reality Learning Environment. In M. Chang, W.-Y. Hwang, M.-P. Chen, & W. Müller (Eds.), *Edutainment Technologies. Educational Games and Virtual Reality/Augmented Reality Applications* (Vol. 6872, pp. 457-463). Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from http://www.springerlink.com/content/l4832n174v9466m4/

Chen, G.-D., Lee, J.-H., Wang, C.-Y., Chao, P.-Y., Li, L.-Y., & Lee, T.-Y. (2011). An Empathic Avatar in a Computer-Aided Learning Program to Encourage and Persuade Learners. *Educational Technology & Society*.

Chen, K.-C., Wu, C.-J., & Chen, G.-D. (2011). A Digital Board Game Based Learning System for Authentic Learning. *Advanced Learning Technologies, IEEE International Conference on* (pp. 25-29). Los Alamitos, CA, USA: IEEE Computer Society. doi:http://doi.ieeecomputersociety.org/10.1109/ICALT.2011.16

Chen, W., & Levinson, D. M. (2006). Effectiveness of Learning Transportation Network Growth through Simulation. *Journal of Professional Issues in Engineering Education and Practice*, *132*(1), 29. doi:10.1061/(ASCE)1052-3928(2006)132:1(29)

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming*, *33*(4), 441 -467. doi:10.1177/1046878102238607

Jiang, J.-S., Chen, G.-D., Wu, C.-J., & Lee, W.-J. (2011). A Scenario-triggered Learning Environment with Augmented Reality for Situated Learning. *Proceedings of the 19th International Conference on Computers in Education*. Presented at the ICCE, Chiang Mai, Thailand.

Jonassen, D. H., Howland, J. L., Marra, R. M., & Crismond, D. P. (2007). *Meaningful Learning with Technology* (3rd ed.). Prentice Hall.

Katerndahl, D. A. (2009). Lessons from Jurassic Park: patients as complex adaptive systems. *Journal of Evaluation in Clinical Practice*, *15*(4), 755-760. doi:10.1111/j.1365-2753.2009.01228.x

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development* (1st ed.). Englewood Cliffs, NJ: Prentice Hall.

Limniou, M., Roberts, D., & Papadopoulos, N. (2008). Full immersive virtual environment CAVETM in chemistry education. *Computers & Education*, *51*(2), 584-593. doi:10.1016/j.compedu.2007.06.014

Liu, W., Cheok, A. D., Mei-Ling, C. L., & Theng, Y.-L. (2007). Mixed reality classroom (p. 65). ACM Press. doi:10.1145/1306813.1306833

Malone, T. W. (1980). What makes things fun to learn? heuristics for designing instructional computer games. *Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems*, SIGSMALL '80 (pp. 162–169). New York, NY, USA: ACM. doi:10.1145/800088.802839

Marshall, P. (2007). Do tangible interfaces enhance learning? (pp. 163-170). Presented at the Proceedings of the 1st international conference on Tangible and embedded interaction, ACM.

Moore's law - Wikipedia, the free encyclopedia. (n.d.). . Retrieved November 28, 2011, from http://en.wikipedia.org/wiki/Moore%27s_law

Ören, T. (2011). A Critical Review of Definitions and About 400 Types of Modeling and Simulation.

Reiser, R. A. (2001). A history of instructional design and technology: Part I: A history of instructional media. *Educational Technology Research and Development*, *49*, 53-64. doi:10.1007/BF02504506

Sawyer, R. K. (2006). *The Cambridge Handbook of the Learning Sciences* (1st ed.). Cambridge University Press.

Schaf, F. M., Müller, D., Pereira, C. E., & Bruns, F. W. (2008). Computer Supported Collaborative Social Environment for Education, Training and Work. *Remote Engineering and Virtual Instrumentation*.

Seitinger, S., Sylvan, E., Zuckerman, O., Popovic, M., & Zuckerman, O. (2006). A new playground experience: going digital? *CHI '06 extended abstracts on Human factors in computing systems*, CHI EA '06 (pp. 303–308). New York, NY, USA: ACM. doi:10.1145/1125451.1125520

Steinberg, R. N. (2000). Computers in teaching science: To simulate or not to simulate? *American Journal of Physics*, *68*, S37. doi:10.1119/1.19517

Sturm, J., Bekker, T., Groenendaal, B., Wesselink, R., & Eggen, B. (2008). Key issues for the successful design of an intelligent, interactive playground. *Proceedings of the 7th international conference on Interaction design and children*, IDC '08 (pp. 258–265). New York, NY, USA: ACM. doi:10.1145/1463689.1463764

Wainer, J., Feil-Seifer, D. J., Shell, D. A., & Mataric, M. J. (2007). Embodiment and Human-Robot Interaction: A Task-Based Perspective. *The 16th IEEE International Symposium on Robot and Human interactive Communication, 2007. RO-MAN 2007* (pp. 872-877). Presented at the The 16th IEEE International Symposium on Robot and Human interactive Communication, 2007. RO-MAN 2007, IEEE. doi:10.1109/ROMAN.2007.4415207

Wang, C.-Y., Chen, C.-hung, Wu, C.-J., Chi, Y.-L., Lee, J.-H., & Chen, G.-D. (2010). Constructing a Digital Authentic Learning Playground by a Mixed Reality Platform and a Robot. *Proceedings of the 18th International Conference on Computers in Education* (pp. 121-128). Presented at the International Conference on Computers in Education, Putrajaya, Malaysia: Asia-Pacific Society for Computers in Education.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, *53*, 5-23. doi:10.1007/BF02504682

Westera, W. (2010). Technology-Enhanced Learning: review and prospects. *Serdica Journal of Computing*, *4*,

159-182.

Zull, J. E. (2004). The art of changing the brain. *Educational Leadership*, *62*, 68-72.