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Exploring Interrelationships among High School Students' Engagement Factors in Introductory Programming Courses via a 3D Multi-user Serious Game Created in Open Sim

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Abstract: The technological affordances of three-dimensional (3D) multi-user virtual worlds and their effectiveness in task-based learning approaches are to a large extent well-established in the international field of computer literacy research. However, less attention was given to their positive or negative impact on student engagement. The current study seeks to investigate the interrelationships of students' engagement among multidimensional constructs consisting of cognitive, emotional and behavioral factors in order to understand better the educational community the learning effectiveness emerged through a 3D computer-supported and multi-user serious game created for introductory programming courses. An instructional design framework based on Papert's theory of Constructionism to be amplified the students' activities and management of their interactions in a 3D multi-user serious game created via an Open Sim standalone server integrated with Scratch4OS is also proposed. Fifty-five (*n*=55) voluntary students from three different high schools participated and experienced in a 3D mind-trap puzzle game named *Co.Co.I.A.* (Collaborative Construction of Interactive Artifacts) to learn basic programming structures. The empirical study findings indicated that student behavioral engagement (attention, retention and energy expenditure for activity completion) had not only a linear correlation with cognitive engagement (learning strategies for the construction of the knowledge domain), but it had also a positive association with emotional engagement (students' positive emotions and achievement orientation) in collaborative learning tasks, causing the reinforcement of the other two factors as well.

Keywords: Programming courses, Open Sim, Scratch4OS, Serious games, Student engagement
Categories: L.3.0, L.3.4, L.3.6, L.3.8, L.5.1, L.6.1, L.6.2

1 Introduction

The international curricula have already acknowledged Computer Science courses and especially programming courses as very important for students to understand the contemporary functions of a learning environment. In fact, programming courses can give many benefits, but undoubtedly convey multi-complex activities that create positive or negative challenges for novice users' motivation and engagement. Thence, many times students' dissatisfaction about the value and appropriate skills that they may gain from these courses are widely expressed. As for the latter, students' skills (logical problem-solving, critical thinking, and computer literacy skills) may favor the extension of other cognitive or collaborative skills of real life more easily in order to solve problems that may be raised in different learning processes. Also, previous studies [Brito and de Sa-Soares 14] [Pellas et al. 13a] have mentioned several restrictions or obstacles. The vast majority of these difficulties are based on: a) the students' misconceptions in understanding the programming signification in their daily life based on the rigorous syntax of text-based computer languages, like Logo or Java, which can become frustrating for novice programmers without the simultaneous execution of actions and structures, b) the students' managerial responsibilities in a graphical user interface (GUI) without their visual embodiment representations during the execution of programming structures, may eliminate the sense of students' co-presence (psychological sense of each avatar to be there with others in a common place) and this provide their negative emotions, c) the lack of students' actions or practice-based consequences in a "faceless" GUI create a sense of disengagement and may not foster their participation, even in collaborative tasks, d) the maintenance cost of a learning environment for the coordination and organization of team-based activities, leading to a large amount of information that cannot be easily assimilated from all participants, e) the limitations of the conventional (lecture-based) instructional format cannot facilitate students' efforts to find several solutions to a problem due to the lack of comprehensive programming functions or modes. As a result, novice programmers do not try to implement activities for the cognitive development of their computational thinking skills, and hence they avoid participating in other future-driven courses.

In this contemporary era of technological advancement, two-dimensional (2D) or three-dimensional (3D) game-based environments have referred to be effective teaching aids in high school computer science courses. As a result, teachers many times face a variety of challenges for the development of engaging and effective course plan. It is generally believed that the major problem stemmed from the challenge of adapting digital natives in a lesson's plan. A growing academic literature body [Paliokas et al. 13], [Pellas 14b] has already suggested that using 3D game-based environments to teach introductory programming concepts can be very advantageous for students' attention, motivation and participation. However, before getting introduced in 3D environments, students should firstly be involved in low-floor programming structures via a low-threshold GUI and a well-established environment to avoid the abruptly information load. After this, students should have the opportunity to implement more complex programming concepts and understandings by using tools or objects in high standards (high-ceiling) activities. This process may help them to gradually be engaged in fading scaffolding learning processes that can lead to more meaningful activities [Su et al. 13].

Scratch4OS due to its ease-to-use GUI can support the construction of event-driven programming in multi-threaded concepts that may lead to the development or reinforcement of students' computational thinking skills. Before the utilization of Scratch4OS, it is crucial to be combined not only with a well-designed learning scenario, but also to be implemented a well-organized educational scenario in a stable environment. Perhaps an interesting research challenge for the utilization of Scratch4OS is the creation of a visually-rich serious game (SG) available to support 3D graphics in real-time and combined with open source virtual worlds (VWs). Open Sim server due to its inherent technological infrastructure allows users (teacher and students) to create and manage collaborative activities in a standalone mode [Pellas et al. 13].

Undoubtedly, the effectiveness of a SG is not the only part of the problem. Student engagement in VWs is a contemporary concept that has taken central role in education, as an inextricably term linked with participatory learning activities that result to the meaningful acquisition of knowledge by the same students. Related studies in 3D multi-user VWs, [Dickey et al. 05] [Dalgarno and Lee 10] have provided some interesting findings regarding the possibility of students' engagement that achieved with their participation where they have common experiences, as fundamental opportunities for collaboration and access to information with other users. The investigation of behavioral, cognitive and emotional factors as indicators of student engagement [Fredicks et al. 04] may also assist educators and scholars to understand the value of a SG held in 3D open source VWs, as a candidate learning platform for participatory activities.

As long as the educational potential and capabilities rising from the use of 3D multi-user VWs, the insightful perspectives may come from the construction of learning tasks in students' hands and thus a theoretical cognitive background is another fundamental point of view that should be always provided at the beginning of each learning activity. Papert's theory of Constructionism can be a potentially useful instructional design framework that supports the pedagogical design of learning experiences held in 3D VWs and Scratch. This view emerged by the fact that 3D multi-user VWs are at the outset game-like learning environments in which practice-based tasks based contemporary learning theories can be adapted. The core of this approach is the co-design, co-construction and co-manipulation of objects in a 3D multi-user environment that gives each student the opportunity to individually or collaboratively explore, experiment or expand his/her horizons of knowledge [Pellas 14b].

This article statement was followed on [Dalgarno and Lee 10] declaration in which they claimed that empirical studies are needed in order to be showed how the characteristics and features of VWs can be pedagogically exploited. The motivation of this study comes from the contribution emanated by the conjunction of Open Sim with free-plug in module, like Scratch4OS that can provide various engaging programming tasks due to [Pellas et al. 13]: a) a low-cost persistent workflow (i.e. a workflow that still exists even when users log out from it and the changes that they have made are permanent) can assist the implementation of different instructional formats (blended/online), b) the technological infrastructure can replicate real-time feedback on users' interactions to create and syntax multiple codes in visually-rich or in realistic problem-based learning settings, c) the a-/synchronous communication tools and realistic aesthetics of a 3D virtual grid permitting users to be engaged in mimicking real life situations, and lastly d) the flexibility and adaptability are unique issues of a 3D virtual grid for users to create at the beginning a learning platform, according to their needs or demands (sense of adaptability). This may help them to organize/coordinate their teams and enhance in these circumstances the sense of co-presence and succeed common objectives.

Recently, there has been started significant research evidence in order to recognize how SGs may impact the learning tasks generally and more specifically to programming environments that easily utilized. A growing academic literature body [Ellis et al. 11], [Pellas et al. 13], [Pellas 2014], [Terzidou et al. 12] has already utilized the technological characteristics of VWs for the creation of SGs and have illustrated sufficiently their learning effectiveness. Nevertheless, a research for the suitability of Open Sim with Scratch4OS to be better amplified the correlations among cognitive, behavioral and social engagement factors (indicators) that may affect students' engagement in participatory learning tasks for understanding better the final value of learning outcomes are still infrequent. Therefore, a research question (RQ) that emerged is if *there is any significant linear correlation (positive or negative) between students' emotional, cognitive and behavioral engagement factors enrolled in introductory programming courses held in a 3D multi-user SG?*

Many instructional technologists [Coffman et al. 07], [Dalgarno and Lee 10] have explored the representational fidelity and interactive capabilities of 3D multi-user VWs in different educational fields, where learning activities are contextualized, with experimentation and collaboration in a common persistent environment to be promoted too. Hence, an additional research is needed on how the factors affecting student engagement toward their practice-based tasks to deploy 3D VWs as candidate learning environments. It is possible to fulfill educational goals by using contemporary learning theories and to reach positive learning outcomes.

The purpose of this study is to investigate the interrelationships among cognitive, social and behavioral engagement factors of students in complex problem solving activities to learn basic programming structures high school students via a 3D multi-user SG. The distinction of student engagement indicators may assist scholars and educators in the context of game-based learning and offer some initial empirically-validated conditions that can guide to the instructional design efforts of other future-driven studies. According to the experimental setup, students have tried to learn basic programming structures (conditions, loops and sequence of structures) by co-manipulating, co-constructing assembled primitives in a 3D mind-trap puzzle SG named *Co.Co.I.A.* (Collaborative Construction of Interactive Artifacts). The present 3D multi-user SG was held in Open Sim and students needed to finalize their experiment by programming primitives with Scratch4OS.

The structure of the present article starts with the Background section that endorses the following subsections: (a) student engagement, its origins and factors affecting learning effectiveness (2.1) and student engagement in virtual worlds (2.1.1), (b) related works about students' perceptions in programming courses in technologically-advanced environments (2.2) and (c) previous works in 3D programming environments (2.2.1) in order to be identified their differences. Then, it is extended the learning process based on the construction of serious games in 3D multi-user VWs (2.2.2) with also a constructionism framework for a SG design to be included (2.3). Moreover, a rationale to be conducted this study analyzed in the subsection 2.4 (the utilization of Scratch4OS and Open Sim for game-based learning) and a thoroughly description of the basic vertical and horizontal design guidelines of a SG prototype in Open Sim are presented. The section 3 has the research method of this empirical study and Results with Discussion are clearly amplified the data regularity (section 4). The Conclusion is exemplified the educational implications (section 5). Lastly, a future work is also highlighted.

2 Background

2.1 Student engagement as a term with multiple dynamic dimensions

2.1.1 Student engagement: Origins and factors affecting learning effectiveness

The term of student engagement describes a learning task or a value referred on the cognitive process, active participation, and emotional involvement of students in specific learning procedures. The study of engagement is valued for both its positive academic outcomes and psychosocial benefits associated with effective learning, acquisition of knowledge and skills. Related studies [Fredericks et al. 04], [Pellas et al. 13b] have attempted to give a definition about student engagement. This term generally recognized by three interrelated factors: i) *cognitive* (CE) refers to the extent and consumption of an intellectual effort that students spent in learning projects (e.g. students' efforts to incorporate the new knowledge into previously well-known patterns and guide their understanding of a study through the use of cognitive and metacognitive strategies). In fact, student engagement in specific learning conditions includes learning goals, student's intrinsic motivation, self-regulation and abilities to implement strategies, in order to elucidate the new knowledge, ii) *behavioral* (BE) stimulates to the responded, degree of active learning, as it also refers to the positive conduct, effort, and student's participation in the classroom and his/her participation in learning processes (e.g. active response of students in a previous teaching, such as the formulation of relevant questions, solving problems and exchange ideas/opinions in discussion sessions with teachers and other classmates), and iii) *emotional* (EE) discerns to the investment and emotional reactions (e.g. high levels of interest and positive attitudes), encapsulating the students' interest and positive attitudes or values about the learning process.

Student engagement in a learning workflow is a very crucial; because it combines students' inspiration, creativity and participation in activities, including the appropriate feedback from the instructor. In these circumstances, it is also crucial to be mentioned that the term of "engagement" can be conceptualized from a plethora of theoretical approaches differently.

2.1.2 Student engagement in 3D multi-user virtual worlds

3D multi-user VWs are increasingly becoming valuable platforms for e-Education in which users (teacher and students) have the opportunity to be fully engaged in collaborative learning processes [Coffman et al. 07]. These "worlds" can be also useful as learning platforms due to their inherent ability to engage students in interactive activities with their teacher and other peers in a virtual class. Users' interactions create a sense of community in 3D visually-rich classes that otherwise might not be configured in face-to-face settings. Learning activities allow students to discover and acquire active experiences that involve or motivate them to explore new study concepts. Usually students follow learning activities that may challenge them to learn by experiencing ("learn by doing") in a common environment, as they have not attended in a passive enrolment, but they have tried to be incorporated in learning approach based on Constructionism and of course under the teacher's guidance [Pellas et al. 13].

Papert's theory of Constructionism is based on constructivist learning theory with a general principle to be the construction of knowledge by the same student in practice-based tasks and direct his/her interaction with the environment. In this way, student can control subjects or re-order the cognitive representations to product meaningful structures. A most common in use instructional principle that can be used is the problem-based learning approach. According to this approach, students are able to learn about a subject by exposing multiple problems in order to construct their understanding deeply through these problems in pragmatic or at least realistic settings [Papert and Harel 91].

By utilizing VWs, users are engaged in situations that mimic those of a real world at a large extent, (co-)design 3D visual prototyping conceptual concepts via constructive tools to gain meaningful insights, and solve authentic problems collaboratively with others in a common place [Pellas 2014a]. Therefore, the student engagement can be considered in 3D multi-user VWs as [Pellas et al. 13]: (i) the level of interaction with other users in collaborative settings is being increased, (ii) the level of feedback given in the virtual environment provided by users or by the system and (iii) the level of commitment promoted by various learning activities that users need to implement.

The effectiveness of various activities in a 3D multi-user VW is connected with the students' engagement, because they can interact simultaneously with other peers as digital-alter egos (avatars) to complete learning purposes focused on the acquisition of knowledge. To this notion, student engagement in specific learning frameworks and the sense of community in online or blended sessions through 3D multi-user VWs can be enhanced by amplifying complex interactions which on their turn may eliminate any boundaries or distracts about their use for learning purposes with positive outcomes.

2.2 Learning programming in technologically-advanced environments

2.2.1 Previous works in contemporary programming environments

Many 2D programming environments were previously created to enhance students' motivation in engaging learning activities [Maloney et al. 10]. However, 2D programming environments seemed to not provide the appropriate feedback directly on students' actions ain a common environment and if there was, it was usually not approval for them (visually or acoustically). In this dimension it was difficult to be enhanced students' collaboration. In conventional class supported activities, it is difficult for users to manage the entire workload borne (management of groups, explanation of the learning material and assistance or prompt feedback on face-to-face processes) in a common environment; thence 3D programming environments started to be structured. Certainly, 3D animation-based environments created in order to motivate students in realistic problem-based situations. Alice is the most well-known storytelling 3D animation-based environment and it was created to encourage students (mainly girls) to participate in object-oriented programming languages [Keheller et al. 07]. PlayLOGO is a 3D Logo-like environment that designed to introduce students aged 6-13 years old in introductory programming courses. The game leveraging the features of videogames, such as narrative to motivate and engage young learners in programming courses [Paliokas et al. 13]. [Kutlu et al. 13] has utilized avatars, 3D spatial sound, and collaboration surfaces in a 3D multi-user VW. Based on a serious game "Zoom", they have improved students' team-building skills in a 3D environment through AvayaLive Engage platform. The potential use of 3D interactive virtual games as a team building environment for virtual teams has been mentioned by [Ellis, 11]. They have developed three games in Second Life (*Crossing the Ravine*, *Tower of Babble* and *Castle Builder*). These games were designed only for improving collaboration between participants and team building skills.

In any case, the contribution of 2D environments like Scratch was important, but perhaps 3D environments could offer more benefits on learning programming, because [Herrera-Acuña et al. 13], [Pellas 14b]: a) students in a 3D environment can enhance more easily computational and higher order thinking skills to solve a problem in different views and perspectives, b) the metaphors of objects or artifacts represented in more realistic situations, c) in many 3D environments students had only one-dimensional (see from the inside a character).Almost all 3D programming games did not allow the collaboration among students, neither was created a team-building climate or a sense of belonging to a team in which students are more familiar in their real life, d) the interactive applications in a 3D environment can usually be explored by the same students, in order to be easily adapted. In addition, experiments implemented in 3D interactive contexts can help more easily novice users to customize pre-constructed virtual places, as they need to share these experiences with others, e) the rapid proliferation of 3D tools may assist the instructional developers to create and modify easier a game-based environment and thus engage students in meaningful and purposeful learning tasks. This may create circumstances that lead to a gradual facilitation of students' engagement from low-threshold to high-ceiling activities more easily.

2.2.2 The construction of serious games in 3D multi-user virtual worlds

Gradually and after 2010, SGs have emerged as worthwhile environments for students' motivation in different educational fields. [Marsh 11] has pointed out that SGs are digital games created via simulations in virtual environments or in mixed virtual reality technologies to provide various opportunities for students' participation through a responsive story, including a specific game play for understanding basic pedagogical concepts. A SG endorses distinguished characteristics which are as follows [Zyda 05]: a) story, art, software are always included, b) accurate representation of the main problem that students usually with the utilization of their personal skills and digital sources try to solve, c) learning concepts through the implementation of specific objectives in scientific fields such as Science, Health and recently in Programming educational fields are qualified.

However, there are also observed some deficiencies using SGs related to: (a) the way that users may communicate and exchange opinions or ideas from the "convectional" computer-supported in 3D environments is lacking [Wang, 04] and the cost of technological-operational assets may impact negatively the utilization of a SG, mainly for urban education [Zyda 05], (b) the lack of rigorous experimentation of simulations and the implementation of theoretical pedagogical models based on socio-cognitive learning underpins in programming courses [Su et al. 2013], and (c) the poor communication or guidance among users may cause also lower level of their general performances in learning tasks. This situation brings also the lack of experimental results to support and investigate students' engagement in SGs that is still required.

Novel developments based on the technological infrastructure of SGs can offer not only realistic experiences, but also favoring to the creation of team-based or collaborative challenges and issues [Hakkinen et al. 12], [Wendel et al. 13]. The wide range of 3D technologically-advanced environments offered some interesting perspectives in the online socialization and learning to geographically distributed (or not) users. But, these environments due to the financial cost for creating simulations and as well as the barriers in time or space to be explored complex situations are not so appropriate to be utilized in public educational sectors. An innovative approach that has attracted scholars' interest was the integration/creation of SGs in 3D multi-user environments [Ellis et al. 11], [Terzidou et al. 12]. Practical implications on game design principles come from the student engagement through explorative and practice-based activities with some of the most fundamental features of typical game-based environments features reinforcing the learning process to be also included. It should be currently hypothesized that a simulation in 3D realistic settings can bring the empowerment of users' emotions that enrolled in learning tasks and expressed their real fears, phobias or even satisfaction and happiness for the courses.

The educational potential and affordances of VWs emanated from their most distinguishing characteristics may be beneficial for teachers and scholars. These are the following [Dalgarno and Lee 10], [Pellas 14a]: (a) 3D multi-user VWs have a high level of accuracy and representational fidelity to be constructed the illustration of realistic situations. While 2D environments have spatio-temporal drawbacks or have been used only for text-based tasks to be exchanged students' opinions in a faceless window-based environment in which they only asynchronously can communicate with other peers, 3D multi-user VWs have given the opportunity of synchronous, real-time interaction of all users (students and teacher) in a common virtual environment. Thus, students can take the appropriate feedback of their teachers or teammates in real-time to solve a problem at the time that it is observed, and not only in class supported (face-to-face) settings, (b) the quintessence of interactive activities that emerged in a common 3D persistent multimedia environment in real-time can offer a simultaneous coexistence of users. These approaches can be enhanced in authentic (or at least pragmatic) metaphors of visual objects or artifacts combined with real-time interactive simulations that refined by rules of the spatial proximity or transformed by the social dynamic impressions which can improve the learning process, (c) the synchronicity of real-time activities, feedback from other peers/teachers and flexibility of time's and space senses to implement different learning tasks according to students' needs or demands, regarding as significant issues of adaption that is missing from the other pre-constructed and simulation-based environments, (d) a/-synchronous communication tools (chat text, VoIP, IM, or gestures for non-verbal) may also assist the development of learning tasks at a distance, something that is already well-known to all young students who play other 3D multi-user role-playing games or environments (MMORPGs) and cooperatively work with others from all around the world, but they cannot understand the potential benefits of co-presence in learning, (e) the (co-) manipulation of time's and space's sense, specifically where students need to practice in a common virtual space to co-create 3D visual prototyping, design easily tangible/interactive artifacts and simulate users' behaviors or characteristics of their artifacts. The co-manipulation of different objects can offer the creation of artifacts using scaffolding process (i.e. conceptual cognitive models or constructs created by the same users and can help them to understand something more intricate in better circumstances based on their teammates' or teacher's assistance), (f) the metaphors of abstract concepts mainly from courses that needed laboratories functions cannot be continued in 2D settings or real life's settings, because of the spatial or space constraints that emerged. In contrast, the sense of co-presence can allow distributed (or not) users to study located in the same virtual grid and not being passive receivers of teacher's information or observers of experiments. Students can take initiatives to be engaged in these tasks without reasonable financial cost and they can also avoid dangerous complications which are often done in real life, and (g) the low-cost or free manipulated pre-constructed grids can assist students to enhance their fantasy and creativity in order to develop something that really belongs to them (narrative storylines or creation of machinimas etc.).

Notwithstanding that has already been provided attention to the implementation of learning scenarios in 3D settings [Su et al. 13] or generally for Computer Science issues in higher education [Terzidou et al. 12], less attention was given for introductory programming courses in high schools and most importantly through the utilization of a SG created in a 3D multi-user world. This may be very useful for activities where either the teacher or classmates can further participate for the creation or adaptation of a theoretical-teaching plan based on Constructionism to create their own knowledge domain. Due to the high cost of creating 3D games often seemed that was not recommended by teachers. Several problems that may not be clarified are how the same students created a proper logical thinking and find different ways to solve problem-based tasks collaboratively with other peers in programming courses.

2.3 Learning principles based on Constructionism

While SGs may motivate students' involvement in learning tasks per se; however it should be analyzed extensively the instructional design framework effectiveness under the light of a certain pedagogical theory or theoretical foundation based on contemporary constructive aspects. According to Constructionism, a learning process can become more effective when people are actively involved in the process of interactive real world objects. Everyone can create his/her own rules, mental models and learning occurs as an adapting process to these models to the assimilation of new experiences [Papert 91]. Thus, parts of students own experiences involved them in learning tasks by manufacturing artifacts with visually-rich interactivity and behaviour ("object-to-think-with"). In this way, Constructionism is connected with the experiential learning and therefore as [Kommers 03] has noticed advanced psychomotor skills in 3D game-like settings and the high representational fidelity can be enhanced. These environments can also facilitate students' activities in a long-term motivation and foster their in-depth learning strategies.

Therefore, there is an urgent need for a practical-teaching background to introduce students via interactive tasks in programming courses based on (socio-) constructive approaches [Su et al. 13]. This situation may allow them to collectively participate or develop their knowledge domain games when they engaged via innovative environments, while gaining cognitive problem-solving skills, communicate with others and exchange of views/ideas in order to better amplify basic programming concepts. The above literature suggests this crucial need. The learning principles that follow Constructionism can become really helpful for students guidance to empower their programming skills in game-like learning environments, in order: (a) to engage students in a persistent workflow that they can easily control role-playing and learning activities and (b) to facilitate an exploratory-creative learning activity in which students actively propose, test and self-reflect upon their ideas to complete a task. According to these benefits, this study hypothesizes that Constructionism can enhance and engage students' learning experiences in game-based settings via a 3D multi-user VW, and thereupon an empirical study was conducted to prove this assumption.

2.4 The utilization of Scratch4OS and Open Sim for game-based learning

An innovative feature that referred in the last three years is the combination of Scratch4OS as a free plug-in module in 3D multi-user VWs. The 2D environment of Scratch has generally low computational requirements (low-floor) and structures that directly affect the requirements of a programming environment (low-threshold). However, the conjunction of Scratch4OS interface with Open Sim can determine a wide range of high-ceiling/visually-rich applications to be enhanced users' technological literacy that can lead to the active production of dynamic interactions or behaviors in geometric solid objects or complex shapes (artifacts) [Pellas, 13a].

Scratch4OS offers to each user a 2D GUI with a pallet of different colored graphical puzzles that include loops, conditional, motion or behavior programming blocks. The simple "copy-paste" method helps users to transfer the code in virtual objects as texts (scripts) to incorporate behaviors and interactions (wide walls), either (a) by introducing "Line Segment" application to interact with visual artifacts and program to paint 3D concepts given by the same user instructions in the local chat of Open Sim or (b) by (co-)manipulating, (co-)creating artifacts or geometric objects and then start to program them, change their size or color by linking them together to construct by programming a more complex one. Scratch4OS has low computational requirements (low-floor) and its' programming structures are directly applied in a 2D graphical pallet for the implementation of students' (low-threshold) programming tasks.

A rationale behind the conjunction of Scratch4OS and Open Sim is proposed according to the multiple opportunities which can be provided for students to learn programming structures [Pellas, 13a] like: (a) the interactive learning opportunities motivate users' participation in collaborative processes, (b) the ownership and easy visualization of programming structures from Scratch4OS to Open Sim, where some changes seemed to be familiar to users. The utilization of an easy modified GUI emphasizes on the design of computational problem-solving activities that resembling as the original one, (c) the visually-rich set of tools allow users to create and syntax multiple codes, and the a-/synchronous communication forms of Open Sim which can help them to organize/coordinate their groups (enhancing the sense of co-presence). These tools provide also the direct feedback on students' actions in real-time, and (d) the potential use of previous knowledge may encourage the construction of a (co-) manipulated and adaptable environment based on Constructionism.

Open Sim as an open source (free of charge) VW is a 3D server-based platform that includes an online, interactive, multi-user virtual environment with a persistent workflow accessible simultaneously by many (distributed spatial or not) users at the same time. The development of SGs in 3D multi-user VWs utilized the potential of computer games to motivate students. This distinction clearly indicates a significant research domain. Thus, the instructional affordances that raised from Open Sim utilization as a standalone server, are as follows [Pellas et al. 13]: (a) low or without maintenance cost performance, in contrast with other social VWs, like Second Life, (b) the virtual grids can be easily modified or co-manipulated by all authorized users in each time, (c) the use of a standalone mode offers portability, transferability, and backup of objects that might be created by all users in a common virtual place, and (d) the macroscopic and microscopic configuration of virtual primitives or artifacts can motivate students to have managerial responsibilities for their activities.

While a specific design framework was not previously proposed by the literature to underline design guidelines for the creation of a 3D SG in multi-user VWs, this paper suggests a "mixed" method based on other previous studies that seemed to be relevant for this scope. The paper utilized a contemporary approach based on the fundamental characteristics of SGs and cyber entities' (avatars) e-profiles which may impact the vertical and horizontal design principles of a SG in multi-user 3D VWs and may promote interactive computer supported collaborative learning (CSCL) approaches. More specifically, it was used: (i) a set of design principles for digital games-based learning experiences [Bober 10], (ii) a serious game-based approach of a multi-player game that have proposed to foster students' collaborative behavior [Wendel et al. 13] and (iii) the design principles of previous works that [Tsiatsos and Konstantinidis 12] have aggregated for the adoption of game-based in 3D multi-user VWs.

Until nowadays, 2D Scratch environment has pay much attention in educators and scholars' rounds to teach basic programming structures (loops, serial sequence etc.), and it is easier for novice users to demonstrate free-scheduled and after school projects based on their creativity and imagination [Maloney et al. 10]. Nevertheless, there is still no evidence on how collaborative activities or design learning principles can assist students to acquire a logical sequence of thinking to solve a problem [Su et al. 13]. This distinction is also necessary to avoid the steep learning curve, as it pretended to be first of all answered questions on how students can collaboratively be engaged in a 3D programming environment that is more complex than 2D one. A problematic pretention in this situation is if the creation of a 3D multi-user SG which can afford Scratch's colored (block-based) utilities created in a stable virtual environment can endorse not only programming constructs in fading scaffolding activities, but also motivate students to solve collaborative problem-based situations in realistic settings. For this reason, it was decided to be utilized Scratch4OS, as a free plug-in via Open Sim standalone server as a candidate programming environment. In Figure1 the main design guidelines of the 3D multi-user SG that was successfully held in an Open Sim standalone server are proposed.

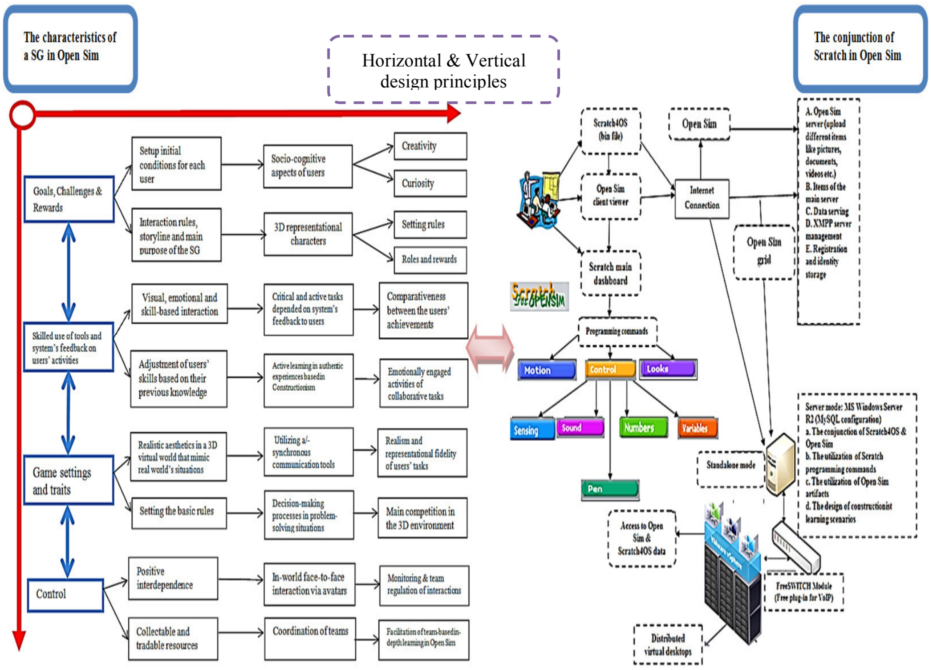

Figure 1: The design guidelines of a SG prototype through Open Sim and Scratch4OS

3 Method

3.1 Setting

This experimental study was carried out with the assistance of fifty-five (*n*=55) high school students knowing really well only the 2D GUI of Scratch, but not Open Sim. The study took 6 weeks and 20 hours of exercise in blended settings (10 hours in schools' computer laboratories and other 10 in supplementary online when the teacher was decided it) in the first triminister of the school year 2013-2014. The teaching of basic programming structures (sequence, selection or loop) took place in the computer lab (7 teaching hours), but students also attended in supplementary online sessions when it was necessary (13 teaching hours). The teacher was always attended to all lessons and accessed materials online and offline (face-to-face). Initially and due to Open Sim, students have tried after this project to co-operate and share information with their friends in other courses.

3.2 Participants

The study sample consisted from three different high schools in Greece participated in introductory programming courses. The sample was chosen randomly from high education establishments. The average age of the participants was 15-16 years old and all of them needed to be participated in several teams of 5 people. Moreover, 28 male and 27 female volunteered participants after the signed consent of their parents. The closed-ended questionnaire after the conclusions of all courses was anonymous and was sent to them via email.

3.3 Instrumentation and data collection tool

The construction of the main instrument was adopted for these programming courses according to [Kong et al. 03] study, translated in the Greek language and it was kept the anonymity of each participant. The overall questionnaire has 57-items emanated from: (i) the *cognitive engagement* with 21-item questions (surface strategy, deep strategy and reliance), (ii) the *emotional engagement* has 14-item questions (interest, achievement orientation, students' anxiety and frustration), and (iii) the *behavioral engagement* has 22-item questions (attentiveness, diligence and time spent to complete a project). Given that the engagement scale from [Kong et al. 03] was originally designed to measure graduate and undergraduate students' engagement in Mathematics, and for this reason we need to modify and measure the student's in-world engagement levels of programming courses. For example, in the Deep strategy (cognitive engagement) subscale when it was asked *"When I learn mathematics, I would wonder how much the things I have learnt can be applied to real life"*, it should be adapted this question with a gap in the case of each course, e.g. "*When I learn programming, I would wonder how much the things I have learnt can be applied to real life*". Thus, it was avoided any misunderstandings about the online high school-level courses that students conducted, and they freely fill the gap in accordance to their face-to-face interactions.

The instrument's validity compromised from the statistical methods that proved its general validity, and thus it was the most prevalent in this study. After completing various activities depicted in Figure 1, voluntary correspondents answered a 57-item self-report questionnaire, according to a 5-point Likert scale (1=disagree to 5=strongly agree). Each part of the questionnaire in web-based format took no more than 15-minutes to be completed and it was sent to students via email. Statistical analyses of the data were performed by SPSS (ver. 22). For the reliability of each factorial structure for the three thematic areas, the Cronbach's alpha index was used and calculated prices that are considered as satisfactory (a_{BE}=0.77, a_{CE}=0.79 and a_{EE}=0.76). To test the RQ a series of statistical analyzes (Sample Kolmogorov-Smirnov test and linear correlation coefficients of Pearson) was followed.

3.4 Treatment

This paper presents a brief overview of a 3D computer-supported collaborative prototype SG (*Co.Co.I.A.*: Collaborative Construction of Interactive Artifacts) and proposed a learning framework based on Constructionism in order to help educators and scholars to understand better the students' interactions and measure the results of their engagement. The core of the present 3D multi-user SG was to be increased: (a) the students' motivation and engagement for learning basic programming structures, (b) the acquisition of collaborative or communication skills and (c) the coordination of students' teams in both blended and supplementary online instructional formats. The teacher's role was to guide students in all weekly meetings and encourage them to think, explore, discover and manage the learning materials in order to solve problems in a constructionism theoretical framework.

Before the beginning of the research process, it was deemed as necessary to implement activities using the blended learning method in three classes with voluntary participation. The participants were asked to perform in a co-manipulation task. All students separated in teams of 5 avatars (11 teams in total in separated time schedules). The students' group that programmed correctly 3D primitives in specific time schedules gained more winning points and finalized the prototype construction.

Several issues of the project that should be investigated are as follows: (a) the access and navigation in Open Sim, whereas purely technical issues resolved in the computer laboratory, and (b) the connection to the 3D VW from students' homes in supplementary online sessions.

The development, configuration and exploitation of 3D puzzle-based and assemble cube-based factory surely helped students to handle the functionality of "objects-to-think-with" artifacts in problem-solving situations as "design exploration metaphors". Similarly, it is noteworthy to mention that trainees were also able to compromise the strength of designing puzzle-based games in a VW. In addition, puzzles denoted a playable exploration by leveraging basic characteristics of a 3D playful mind trap puzzle, as an educational opportunity for students to acquire a synthesizing basic computational thinking skills associated with basic programming structures. Puzzle-assembled primitives with behavior comprised the several tools-smiths, permitted users to create interactively their workshops, to control the problem-solving strategies and to report visually the content of design puzzles. Puzzle-based activities in this stage established as 3D metaphorical programming experiences than simple mechanisms of 2D design puzzle-based representations.

3.5 Experimental setup

In the experimental setup students need to efficiently collaborate and program artifacts in Open Sim, where they must firstly develop all eight (8) 3D "interlocked" puzzles in a shared virtual space depicted in an old ready-collapsed factory. Students firstly constructed and then tried to replace the 3D "assembled" mind-trap pieces (i.e. modified visual primitives as they attended like civil engineers) in a co-manipulation task. To complete these task students tried to communicate (verbally or text-based brainstorming) with their peers. Apparently, they should program how to carry on in each truck only one visual primitive every time. Then, students tried to assemble every piece with others in order to exchange visual-spatial information, such as positioning a visual object, and programming every interlocked piece with a sequence, selection or loop programming structures to construct each side of 3D shadowed-colorized nets. Regarding the construction of each factory side, students should upload correctly the 3D assembled primitives on the magnet crane and avoid its collapsing. The re-construction was based on assembling primitives in physical settings. Students firstly planned and then built the interactive behavior of each assemble artifact copy-paste the writing program code from Scratch4OS in order to both collage each cube with other ones. Then, they should try to conjunct it via loop structures to the crane and finally estimate how to put it correctly but not collapse each side of the factory.

This experiment was conducted because students need learn to communicate in a 3D multi-user virtual space and understand how they can co-construct or co-manipulate a common spatial representation in Open Sim. Moreover, some crucial constraints were introduced in order to prevent team members from sharing implicitly the same viewpoint and by having a direct access to their teammate's field of view. At first, each user's starting viewpoint was different from his/her teammate's starting viewpoint for each new 3D prototype artifact. Then, users were freely modified their viewpoints during the task, which helped them to avoid complex mental rotations to co-manipulate the virtual objects. However, no feedback was given about the others' viewpoint and spatio-visual option of each one limited in order to communicate and collaborative with others. Additionally, several constraints were introduced to prevent the quadrats from being used as contextual references instead of the stable lateralized visual landmark: (i) all quadrats should have fairly dissimilar geometric shapes, and (ii) all quadrats should not be lateralized, analogous to their right, left, front or back sides are always dependent on each student's position that wanted to start programming and placing each piece in the nets of the 3D puzzle.

Collaboration in problem solving tasks was provided in the present 3D multi-user SG, because it could promote students' reflections and enhance at a large extent the learning process. Open Sim enables collaboration via synchronous communication tools among avatars in a common virtual grid to edit the same primitive and share the same code while programming it with Scratch4OS. All users (students and teacher) had the opportunity to access and leave in-world objects or messages to the other members (group of 4 avatars as a team or private messages-IM). When a user seeks to provide a solution on how to program or collide a primitive successfully logged in all his/her messages and he/she can see all the objects left in this world by others where permissions were set. Figure 2 depicts an example of virtual prototype 3D "assembled collage" in the front nets of the cube according to the experimental setup.

A collection of awards was also included in this 3D multi-user SG to sufficiently motivate and engage students. Beyond the basic winner prize there were a set of other awards determined the final winner team in case of a tie. The awards are the following: (i) "*write the code correct":* it was given to the group that has correctly written all programming codes, (ii) "*degradation of the problem in right settings":* it was given to the group that has discovered the largest number of questions to solve the problem, even if finally they have not answered them correctly and (iii) "*best short time spent to assemble and program interactive artifacts" award:* it was given to the group that assembled and programmed correctly almost all the artifacts without destroying the side of the ready-collapsed factory.

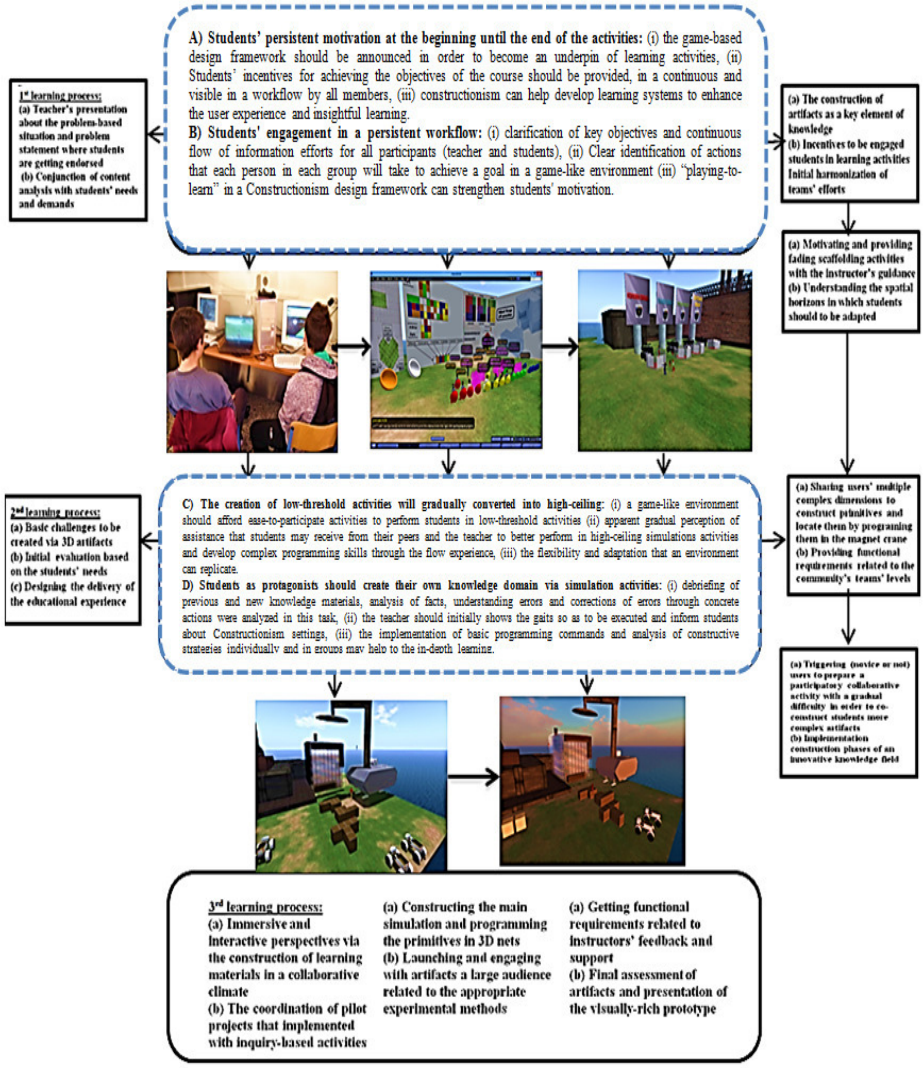

Figure 2: The proposed learning framework based on Constructionism

4 Results and Discussion

The Pearson's correlation coefficient to be answered the overarching RQ and to be amplified the data regularity was used. For the reliability and validity of this study the sample of 55 students was regarded as essential. The descriptive data conducted via correlations of the test normality Kolmogorov-Smirnov (Table 1). It was also observed the average (Mean-*M*) of the three engagement indicators at almost high levels (M_{BE}=4.09, M_{CE}=3.87, M_{EE}=3.58), in which BE factor had the highest value.

All variables had statistical significance (p-value) higher than 0.05 (p_{BE}=.382, p_{CE}=.394 and p_{EE}=.447). There were indications that the measurements of variables were followed with normal distribution. In Table 2 the linear regression of the Pearson's analysis is described.

		BE	CE	EE
Normal Parameters	Mean	4.09	3.87	3.58
	Standard Deviation	.74	.65	.71
Most	Absolute	.112	.135	.154
Extreme	Positive	.084	.121	.441
Diference	Negative	-.245	-.074	-.254
Kolmogorov-Smirnov Z		.841	.522	.884
Asymp. Sig. (2-tailed) [p-value]		.382*	.394*	.447*

*Significant at p<.05

Table 1: Descripitve results and normality test

According to Table 2, a statistically strong positive correlation between BE and CE indicators with a coefficient of linear correlation (r=.643) is noticed. This suggested that by increasing social and emotional competence in an activity, simultaneously it was increased the index of CE through exploratory and collaborative activities. Summing up the aforementioned, it can be also observed that there was a positive linear correlation between the two indices. Furthermore, it was appeared that there was a linear correlation of BE and EE (r=.558). This association brought to the front the users' sociality feelings. It also increased the students' initiatives in an organizational-teaching constructionism framework that facilitated the acquisition of programming structures. After completing several activities in Open Sim, BE was ascertained to have a positive linear correlation both indices of CE and EE.

		BE	CE	EE
BE	r	1	.643**	.558*
	P		.001	.023
	r^2		.632	.079
CE	r	.643**	1	.128
	P	.001		.053
	r^2	.632		.068
EE	r	.558*	.128	1
	P	.023	.053	
	r^2	.079	.068	

*Significant at p<.05; **Significant at p<.01

Table 2: Pearson's linear correlations

The study results showed a positive aspect that eventually impacted students' engagement in participatory learning tasks and associated with sequence, selection or loop programming structures when they collectively co-create, experiment and program complex 3D puzzles. This experiment enhanced their positive conduct and behavior (BE) for programming courses. Students also acquainted in team-based learning tasks based on Constructioniosm (CE). Practically, BE in a collaborative climate for the cognitive learning involvement of students, where social interaction and positive feelings about in different learning situations engaged students widely. If the major concern for teachers is how to support effectively the students' collaboration in 3D multi-user VWs, then the appropriate conditions, in which all of them can interact not only freely with the learning materials, but also with other peers, should be created per se. [Pellas et al. 13a] have referred that social presence not only enhanced students' social interactions at high rates in game-based activities, but also it reinforced critical thinking and learning the degradation of a realistic problem should be implemented in well-organized settings.

[Paliokas et al. 11] argued that a 3D game-based environment can help students to understand basic programming structures. As they also stressed the transfer of language in 3D Logo-like environments with playful characteristics that can demonstrate a positive impact of young students in programming courses, this study proved that a 3D multi-user SG assisted students' engagement. Lastly, students' roles always formed in a collaborative climate and increased their positive attitudes to collaborate with other peers (EE). The hybrid instructional format assisted also students to become gradually seekers of knowledge and not passive recipients of the teacher's instructions.

At the end, the study results reflected not only to the increased performances of all students, but also to the performance of each one that independently empowered their engagement indicators. Furthermore, the attentiveness and time spent for educational activities (BE) seemed to be directly correlated with the exploration, collaboration, teaching plans for the organization and construction knowledge (CE). The fundamental tendencies for computer science courses such as interaction, sense of co-presence, 3D embodied representations and the challenging persistent workflow motivated students to attend and participate in this 3D multi-user SG. Thereupon, student engagement in these perspectives considered as a valuable parameter for more successful learning outcomes in introductory programming courses.

5 Conclusion

The results of this study suggested that an instructional design framework based on Constructionism helped students' coordination in the 3D virtual grid with learners' motivation and cognitive programming structures via scaffolding processes maintained their commitment at a high level during the game. By understanding the interrelations between student engagement factors, both theoretical insights and educational practices enriched. It is equally important to be noted that this study findings should be taken into account in order to carefully design instructional technologists of SGs and maintain students' motivation and commitment at high rank levels. These are: (i) the interactive 3D multi-user GUI refers to the direct interaction between players and game systems, (ii) the orientation of specific goals achieved in a constructionism framework, and (iii) the social interaction and relationship among students ascribed to communication and cooperation in problem-solving situations and directly influenced the solution in participatory settings. According to previous studies [Dickey, 05], [Pellas, 2014a] these three elements are also important for student engagement.

The formation of a well-structured and multi-factorial learning framework can facilitate users' interactions and lead to the refinement of their cooperation, communication and engagement. This discrimination suggested that unique constructs and issues posed to students' engagement guiding teachers to determine the suitability and usability of 3D multi-user VWs in particular learning tasks. Student engagement should be further combined in a broader context through their participation and motivation in order to essentially participate with other peers in a collaborative learning activity. The results have shown that the BE (students' on-task behaviors) was significantly positive correlated with the CE (expression of students' solutions in problem-based tasks) and EE (students' on-task satisfaction). These interrelationships brought a linking part between performances in-/extra-curricular class-oriented strategies via problem-based activities that are particularly important when group members utilized artifacts and tools in a 3D multi-user VW.

The limitation of an age-homogeneous sample, but heterogeneous on its cognitive domain can also become a crucial parameter for the students' answers. The learning framework based on Constructionism was truly acknowledged that helped students' interactions in specific learning situations and gave a first positive impact on the role of trainees' programming constructs in Open Sim. These results brought to front other crucial pedagogical issues, such as the sense of sociability, interactivity and collaboration that emerged among students' engagement in collaborative tasks. This can contribute and serve new forms of engagement indicators and their impact on students' overall performance.

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