EMOCASH: An Intelligent Virtual-Agent Based Multiplayer Online Serious Game for Promoting Money and Emotion Recognition Skills in Egyptian Children with Autism

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***Abstract*—Autism, often known as "autism spectrum disorders (ASD)," is one of the most common developmental disabilities that affect how people learn, behave, communicate, and interact with others. Two crucial everyday tasks that people with ASD typically struggle with are managing finances and recognizing emotions. As the online gaming sector grows and develops, the question of why this type of media can't be used as a useful educational tool for those with ASD arises. This paper discusses this issue via a novel virtual agent-based multiplayer online serious game referred to as "EMOCASH," which aims to improve these important tasks for Egyptian children with ASD and achieve transfer of acquired knowledge to real-world situations via a 3D virtual shop scenario that was designed using the Autism ASPECTSS™ Design Index. EMOCASH served as an instrument for investigating the following research question: What role does technology play in the education of those with ASD? Numerous sub-questions that were related to the primary question were also addressed. A variety of usability metrics were used to assess effectiveness, efficiency and satisfaction aspects.**

***Keywords*—Autism; virtual agents; serious games; digital technology; AI; online gaming; usability and accessibility**

I. Introduction

Individuals with ASD frequently experience difficulties in daily living skills, including conceptual, social, or practical skills. The importance of daily living skills for people with ASD is especially important since they have a direct impact on the growth of abilities like self-determination and autonomy [1]. Numerous studies have used technological interventions to enhance the daily living (DL) skills for individuals with learning disabilities, including housekeeping [2], first aid training [3], money management skills [4]–[7], learning math subject [8], raise awareness about the effects of littering in [9] and diabetes in [10]. Scholars discovered that people with ASD commonly suffer from mindreading, or theory of mind (ToM) skills [11]–[14], and anthropomorphism, which is the extension of ToM to non-human agents [15]–[16]. ToM refers to our ability to observe the mental states (intentions, emotions, knowledge, and beliefs) of other people. Previous work [17]-[21] reported that autistic people's ToM skills are less developed when they mind-read human beings than when they mind-read non-human agents having anthropomorphic traits, such as animals and cartoons. For instance, the authors of [21] demonstrate how anthropomorphizing faces—that is, placing them on objects like vehicles—can help people with ASD better recognize emotions. We carried out a study by expanding this idea to assist Egyptian children with ASD in practicing handling money, recognizing emotions, and teaching them how to behave properly in a shopping center using a collaborative authentic learning environment (CALE) instead of the conventional on-screen display apps. The app shows autistic children the potential everyday activities that could happen when a child goes shopping. Contrary to prior approaches, the learning environment was designed using the Autism ASPECTSS™ Design Index [22], [23] to adapt to the needs of all types of users. Moreover, the scenario supports multiplayer, which is more engaging and motivating than single-player training games. We expand on these foundations. The paper is organized as follows: the problem statement, the research questions that were raised, and the purpose of this paper are presented in Section II. Section III discusses previous studies connected to both money management and emotion recognition for people with ASD. Some theoretical background is summarized in Section IV. Section V introduces the methodology used. The development processes of the proposed system, including system architecture, design, and implementation used to develop the system, are presented in Section VI. The clinical characteristics and practices of the participants are listed in Section VII. Section VIII describes the different usability metrics used to assess the effectiveness, efficiency, and user satisfaction of the produced application, along with a comparison with existing techniques. Section IX concludes the paper and highlights future work.

II. Objectives and Research Questions

While transitioning from adolescence to maturity, everyone must take a huge and difficult step. Because of their impairment symptoms, people with ASD typically have significant problems carrying out basic daily tasks on their own. Traditional intervention techniques, including the Picture Exchange Communication System (PECS) [24], social skills classes, narrative, role-playing, and so on, are costly, time-consuming, staff intensive, boring for patients due to exercise repetition, and usually have long waiting lists, rendering them ineffective. Internet-driven rapid advancements in ICT, such as serious games (SGs), VR, AR, virtual agents, AI, and robot,

among others [25]-[30] have opened creative and promising scenarios for therapists to improve DL skills for individuals with ASD. However, studies on how using authentic learning environments and engaging in online games affect learning outcomes for those with ASD are noticeably lacking. Taking into account the importance of user-built environment interaction for autistic persons, this paper addressed these issues using an innovative virtual agent-based multiplayer online SG called "EMOCASH," which served as an instrument for investigating the following research questions: (1) Is it possible to employ agent technology to create intelligent agents that can be included in online games for persons with ASD? (2) What advantages do online games provide for people with ASD? (3) How can we improve the appeal and motivation of education for those with ASD? (4) Which learning environments are most effective for this purpose? (5) What aspects of game elements are taken into consideration when using online gaming to educate autistic people? Concerning the first and second questions, the usability of virtual agent technology via online gaming for people with ASD is investigated in this paper using CALE. Online gaming enhances user experience, encourages immersion, social interaction and competitiveness, reduces autism symptoms, and promotes the satisfaction of working independently. When playing an online game, there is no eye contact or facial expression required, which can help reduce anxiety and any other unusual behaviors. Online games give people with ASD the opportunity to interact with their peers in a safe and less stressful learning environment that does not require regular face-to-face interaction; as a result, they can build communication skills that promote friendships and socializing (For instance, please refers to [31]-[34]). Regarding the third and fourth questions, we employed the Autism ASPECTSS^{TM} Design Index [22] to accommodate specific autistic needs as a design development tool to support environments conducive to learning for those with ASD. The concepts of authentic learning [35]-[36] and authentic design thinking [37]-[38] were also used. In the methodology section, numerous key game elements will be examined together with relevant information on each one's usefulness for our developed game in response to the fifth question.

III. Related Work

The use of serious games (SGs) to teach DL skills to persons with ASD has been proposed in a number of studies. These studies were categorized into four categories: conceptual (e.g., money, science, etc.), practical (e.g., use of money, travel and transportation, etc.), social (e.g., emotions, communication, etc.), and general skills. According to [30], the percentage degree of studies targeted at all of those learning categories is given as follows: conceptual skills (25.53%), practical skills (8.51%), social skills (36.17%) and general skills (29.79%). Furthermore, 1.06 percent of research papers were devoted to discussing money management techniques for those with ASD, demonstrating the pressing need for more studies in this field. Different DL skills such as money management skills [4]–[7], emotion recognition [39]-[45], among others have been successfully improved using SGs in special-needs education. However, those methods would not fit with the Egyptian lifestyle, currency and language. As an illustration, Caria et al. [5] designed a single-player Web-based game that assists people with ASD in acquiring skills to help them understand the notion of Euro currency and its usage in real life in comparison to Bangladeshi Taka currency [7]. The authors in [45] conducted an intervention program using animated vehicles with real emotional faces to improve emotion recognition for Chinese children with ASD compared with Western children in [21]. Additionally, the vast majority of earlier studies concentrated on a single player in a two-dimensional gaming environment, whereas there is a notable lack of research on the development of collaboration skills through multiplayer online games in three dimensions, which support emotions and social interaction among participants and are more engaging and motivating than a single player. One more significant issue is that designated learning environments need to take sensory issues into consideration in order to meet learners' demands. This paper considers all these issues by applying the Autism ASPECTSS^{TM} Design Index [22] as a design development tool for the EMOCASH game's environment. ASPECTSS^{TM} is an abbreviation for: Acoustics, Spatial Sequencing, Escape Space, Compartmentalization, Transitions, Sensory Zoning, and Safety.

IV. Background and Fundamental Concepts

A. Serious Games

Serious games (SGs) are a form of education and entertainment that is designed to educate as well as amuse. Unlike games that are just played for fun, games intended for learning are labeled "serious" [46]-[47]. The key concept of serious gaming is the implementation of gaming elements, attributes, mechanisms and flow states to engage learners toward achieving real-life goals.

B. Activity Theory

Activity Theory (AT) is a theoretical framework for examining how people behave in a certain setting. According to AT, the essence of an activity is the interaction between a subject (a human doer) and an object (the item being done). Activity systems [48]-[49], a model of which is shown as a triangle (see Fig. 1). Simply, activity theory is all about 'who is doing what, why, and how' [49].

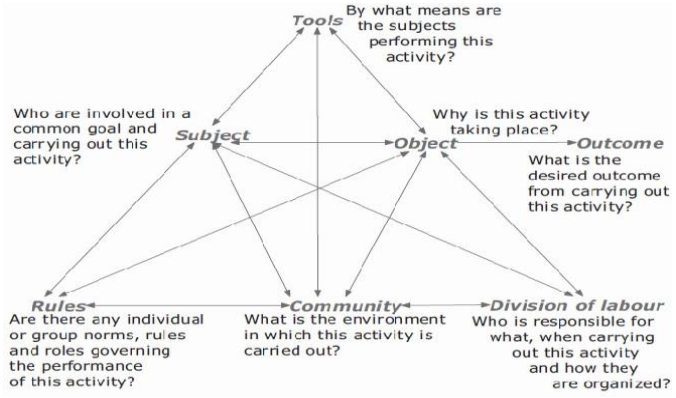


Fig. 1. Structure of activity theory.

C. Virtual Learning Environment and Virtual Agents

The term "Virtual Learning Environment" (VLE) refers to a design environment for teaching and learning. There are several types of VLE, such as single-user, multi-user, and collaborative VLE (CVLE) [50]. Each one of them has a unique avatar that the user may use to engage freely in the digital world. Avatars might take the form of a cartoon character, an entirely abstract shape, or a human-like image. The avatar in our system is a 3D representation of a rabbit with real faces grafted onto it. A software system that is embedded in a particular environment and has the capacity to behave autonomously there in order to achieve its design goals is known as a virtual agent, also known as an intelligent virtual agent (IVA) [51]. IVAs should be autonomous, proactive, reactive, and socially capable. There are several AI agents, so an environment for the IVA design work has to be created, which is called the PEAS (Performance Measure, Environment, Actuator, and Sensor) system [52]. The PEAS System is used to classify similar agents together. An agent's success is assessed using performance metrics; an actuator is a part of the agent that releases the action's output into the environment; and sensors are the receptive parts of an agent that takes in data. The qualities of the environment influence an agent's behavior [53]. Different types of intelligent agent programs based on their degree of perceived intelligence and capability are used in AI, namely: reflex agents, model-based agents, goal-based agents, utility-based agents, and learning agents [52]. Each kind of agent program combines particular components in particular ways to generate actions. The EMOCASH game uses reflex agents where the agent function is based on condition-action rules as demonstrated in Fig. 2.

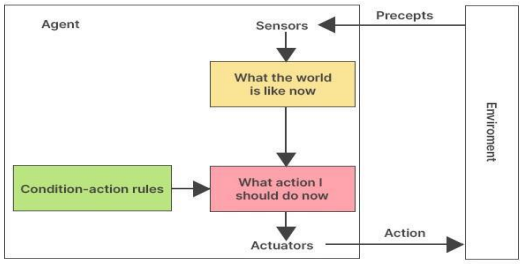


Fig. 2. Schematic diagram of reflex agents program.

V. Methodology

A. Methodology Workflow

According to contemporary conceptions of effective learning, learning is most successful when it is proactive, reactive, social, experiential, problem-based, and offers quick feedback [48]-[49]. Learner achievements and engagement, as well as active learning, are the two major elements of effective learning. One of the most significant elements influencing learner achievements, success and outcomes is the learning environment [53]. According to the sensory definition of autism [54] the problem of the sensory environment and its relationship to autistic behaviour appears to be the key to designing for autism. This description serves as the foundation for the Autism ASPECTSS™ Design Index [22], [23] which we employed in our methodology as a design development tool for the EMOCAH game's environment. For active learning, learning environment should be authentic with authentic tasks. Learning in the real-world is authentic learning. To support learners' engagement towards the 21st century skills, the concepts of authentic learning and authentic design thinking [35]-[38], should be employed in educational contexts. In order to engage learners in 21st-century skills, service providers must consider the following five dimensions of 21st-century skills, which were in-depth examined in [37]: cognitive, metacognitive, social-cultural, productivity, and technological. Design thinking (DT) shows a variety of characteristics when used in educational contexts, according to [37] in chapter 9. These characteristics include: 1) DT comes out of social processes where ideas are being formed, clarified, and refined. Collaboration is an important foundation for DT in educational settings; 2) DT involves knowledge creation and is more closely characterized by an iterative and non-linear process that contains five phases (Empathize, Define, Ideate, Prototype, and test), as illustrated in Fig. 3; and 3) DT doesn't have well-defined and well-ordered design stages. Instead, ideas go forth and backward through social interactions until they are wholly embraced by the team. Training individuals with ASD necessitates repeating tasks, which might reduce participants' motivation and interest. To maximize the training outcomes while maintaining the participants' motivation, our methodology takes into consideration the idea of authentic design thinking, game elements' diversity, game attributes, and task activities and introduces an activity system as a framework to embed intelligent agents in SGs' development, as shown in Fig. 4.

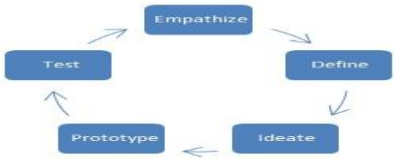


Fig. 3. Design thinking (DT) cycle.

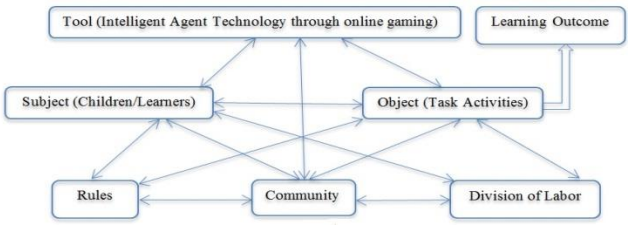


Fig. 4. Learning as an activity system.

As demonstrated in Fig. 4, this system effectively combines learning and technology while also capturing real-world learning environments, which is essential for 21st-century skills [37]. Task activities are the activities and interactions designed to keep the learner engaged and learning in the game's environment. In our approach, the task activities are used as the building blocks of the SG design, and the learning objectives are defined according to the kind of tasks, their number, and difficulty. We now respond to the research question listed in section II: How can we improve the appeal and motivation of education for those with ASD? Authenticity and sensory design aspects [22], [54] should be addressed throughout the design phase of the specified learning

environment. This produces the answer to this question. When the word "authentic" is added to the term design thinking, it transforms into a creative process that aids service providers in coming up with meaningful approaches to their issues by giving them the chance to experiment, develop and prototype models, gather feedback, and redesign instructional materials to improve their learners' learning and performance. Therefore, the finest resource is your expert judgment and relevant stakeholders. As shown in Fig. 5, the methodology workflow is iteratively developed and built from the study of the core design components of an authentic learning environment [35]-[36] and authentic design thinking [37]-[38], as well as the following rules and recommendations that are directly gathered from relevant stakeholders in the area of special needs education using a multi-stage process known as participatory design or a similar user-centered design (UCD) [55]. UCD is defined as a philosophy that places the learners at the center of the design process, taking into account their characteristics, needs, skills, desires, behavior, etc.

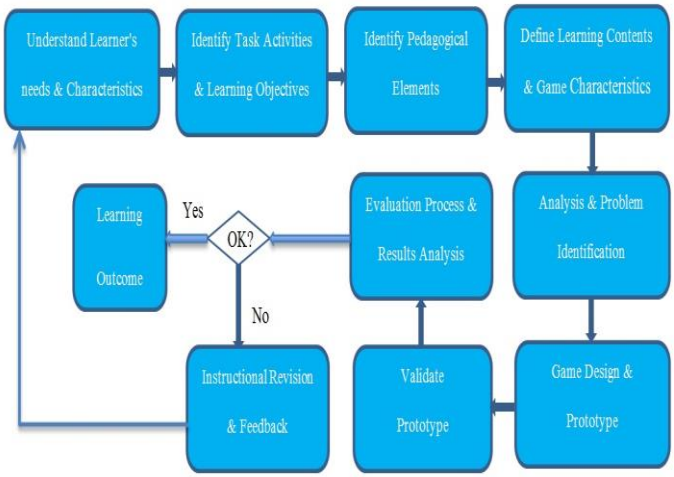


Fig. 5. Methodology workflow.

- Learner-centered: The interests and desires of your learners need to always be your starting point. What, for example, are their interests and needs? What engages them?
- Based on your learner needs, determine a possible goal or outcome. Link the outcome to anything in real life to highlight relevance and authenticity (e.g., shopping in the supermarket, in our case).
- Divide the skills your learners will learn in order to accomplish the outcome.
- Assess your learners both before and after teaching: How do they now perform in these skills? What do they now know? What new skills do they now have? This issue was addressed in our case through usability testing in terms of learnability rate.
- Community-driven design: Individuals struggle to address the entire system; a multidisciplinary group of people with a range of expertise is required to find a solution. We employed the idea of participatory design [55] to satisfy the needs and preferences of the learners in order to accomplish this goal.
- Give the AMT model some attention: Provide learners with the opportunity to concentrate on the three learning goals of acquisition, meaning-making, and transfer (AMT), as shown in Fig. 6.

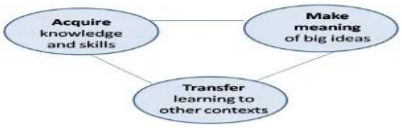


Fig. 6. The AMT model.

B. Pedagogical Agents

To facilitate and improve the learning process, virtual characters, or artificial agents, are commonly used in computer games via a VLE. These individuals, also known as "pedagogical agents," may serve in a range of roles, including that of teachers, subject-matter experts, mentors, motivators, or companions [56]. Pedagogical agents are computer agents designed and built to support education by enhancing learners' capacity for spontaneous recall and information retention. It has often an animated persona that responds to the action of the learner [57]. Numerous pedagogical agents have been created and assessed by scholars from different perspectives [58]-[60]. We used anthropomorphic agents—3D models of rabbits with real faces superimposed on them—to construct the pedagogical agents for the EMOCASH game. Additionally, we made an effort to make the rabbit's form larger in order to grab the child's attention. Similar findings have been made by [17]–[19], who claim that autistic individuals' ToM skills are less developed when they read the minds of humans than when they read the minds of non-human agents with anthropomorphic traits like animals. The EMOCASH game may be played by many users using a CALE, and users can interact with one another via their pedagogical agents (see Fig. 7).

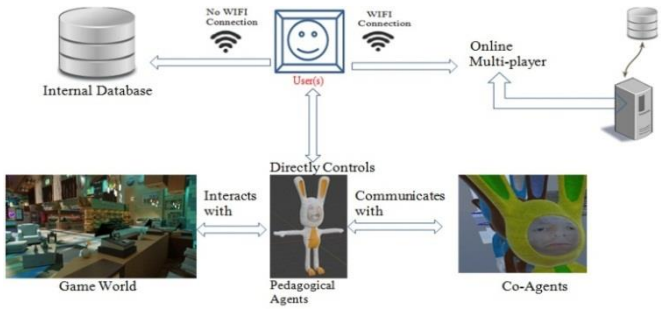


Fig. 7. An illustration of a CALE with pedagogical agents.

C. EMOCASH Gameplay

Gameplay defines how the learner and the game interact with each other; it simply means playing the game. EMOCASH gameplay is briefly discussed below:

- The psychologist describes the therapy process. To start the game, each participant has to log in.
- Game Acts: It is defined as the highest-level element in the EMOCASH game which is divided into many

parts, including the registration page, login screen, play mode, evaluation mechanism to allow tracking of players' progress, etc. Six distinct types of 3D mini-game engines, each with a different level of difficulty, are included in the play mode. Participants must register the first time they play the game. Each participant's results and learning progress are tracked in the assessment file folder.

- Scenes: The gameplay takes place in acts, where each act is divided into scenes. Scenes take place in one or more scenarios with different levels of difficulty.
- Therapeutic game challenge: The essence of the gameplay is the challenges-actions relationship (what challenges the game has and what actions the player can take to achieve the goals).
- Currency recognition mini-game: This mini-game attempts to help autistic children recognize the several primary Egyptian cash denominations and their corresponding values as a tutorial via two engines. The first engine that will be shown is an animated book (GameBook) that has all the major Egyptian cash denominations. The participants' task is to open each page, see and freely move the provided cash notes in all directions in accordance with the six DOFs as depicted in Fig. 8(a). The second engine's job is to put together an image of the currency note (e.g., a one, five, ten, twenty, etc.) from a variable number of pieces that are spread out across a table surface in random placements. The puzzle's final appearance after being properly solved is depicted by a target image in the upper portion of the screen. The task requires the participants to piece together the required image using the materials they have collected, as illustrated in Fig. 8(b). By the time the session is over, the participants will have two levels of easy quizzes that gradually get harder. For instance, we ask the participant to choose one of four currency notes that are displayed on the screen.

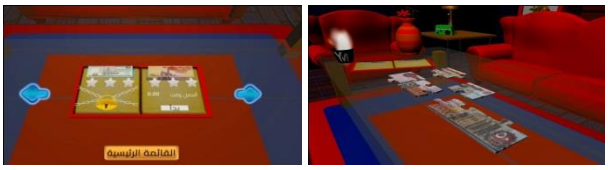


Fig. 8. (a) An animated game book containing all Egyptian currency denominations (b**)** Puzzle game.

- Emotion Recognition mini-game: With the use of numerous settings for purchasing (such as being a customer) and selling (such as being a cashier) inside a 3D virtual shop environment, this game enables autistic children to reinforce some facial expressions used when shopping. For instance, if you need to buy something but don't have enough money, you'll feel "sad"; alternatively, you'll feel "happy." When asking for assistance when shopping, the same feelings will manifest as depicted in Fig. 9. To engage participants and confirm that they were able to understand the required activities, the game start-up user interface featured a tutorial for an animated human cartoon face with distinct emotions incorporating visual and audio stimuli (see Fig. 10).

(a) A snapshot of some players asking for some assistance

(b) The message indicates that the player received a favorable response (a happy feeling)

(c) A snapshot of some players asking for some assistance

(d) The message indicates that the player received an unfavorable response (a sad feeling)

Fig. 9. Snapshots of recognizing some human facial emotions in various contexts while shopping.

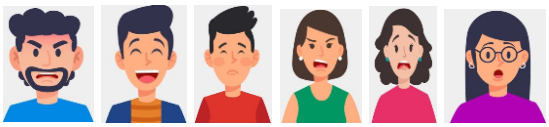


Fig. 10. A Screenshot for an animated designed human cartoon faces with different emotions.

- 3D virtual shop scenario: This mini-game aims to teach the process of shopping to autistic children by achieving the transfer of acquired knowledge to a real-world scenario, such as shopping in the supermarket. The scenario employs a (CALE) with a simplified navigation and interaction interface that encourages emotions and interactions among participants, who can play alone or with their instructors. For agent movement in a virtual world, the A* (A-Star) path-finding search algorithm is used [61] (see Fig. 11). It addresses the problem of finding a shortest path from any coordinate in the game world to another.

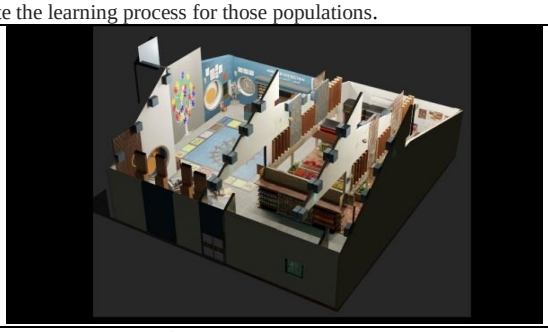
Fig. 11. The A* (A-star) algorithm in action.

- By the end, feedback sessions are planned and the results are analyzed.

D. Game Elements and Attributes

The parts that make up a game and give learners an engaging experience are known as game elements. Every game element must have attributes that may be utilized to affect how they are used when developing SGs. Scholars [5], [62]-[64] have reported that incorporating game elements into teaching methods for people with ASD can improve their learning abilities. For instance, the authors of [62] consider game elements as intrinsic and extrinsic factors to increase a learner's motivation. The majority of previous research did not explicitly identify the game elements or specifically state or offer information on the games' elements they employed while creating their solutions. Even when they did, they didn't provide adequate information on the efficiency of the particular game elements. We now respond to the research question listed in section II: What aspects of game elements are taken into consideration when using online gaming to educate autistic people? The EMOCASH game offers a variety of useful game elements with relevant information on each one's effectiveness, as indicated in Table I.

TABLE I. EMOCASH'S GAME DESIGN ELEMENTS FOR LEARNING

Game Elements	Description
Game World/Environment	It is a virtual environment where players go while playing the game. As illustrated below, the gaming environment in the EMOCASH game is created as a 3D virtual shop scenario based on the principle of authentic learning with authentic tasks, like grocery shopping, for teaching the shopping process to autistic children. It was designed in accordance with the Autism ASPECTSS™ Design Index [22], [23], [54] to take into account the specific needs of autistic people and facilitate the learning process for those populations.  
Clear Goals	When people are aware of their responsibilities, the goals are crystal clear. Giving meaningful challenges and establishing clear norms are closely tied to setting clear goals. Clear objectives improve attention. To hold players' attention and make sure they will be able to understand the necessary tasks, the primary objectives and rules of each mini-game are given at the beginning of the introduction to the entire EMOCASH game.
Challenges	Challenges are game tasks or exercises that require effort to perform. In the EMOCASH game, there are a lot of tasks for each mini-game to be completed. Once achieved, some rewards are provided.
Rewards	A reward is a component of the game that gives the players satisfaction and inspires them to work harder. Extrinsic rewards, such as points, badges, and leader boards, are available through EMOCASH, as well as intrinsic rewards, which are given for successfully completing each mini-game throughout the entire game in exchange for resources (such as earning virtual currency with a numeric value) and reputation (such as a certain number of stars).
Best Moments	It is a fun feature that motivates the participants during the game. The virtual gained items from the prize gallery are stored in an inventory which can be reached by clicking on the "prizes customization" button on the main screen to enable the participants to experience a personalized training by meeting their curiosity and virtually using the items (e.g., wearing a glass) through a variety of customization options.
Status	The status is a categorization of participants based on their scores. In EMOCASH, the motivation is based on the aim of participants to reach a high status by earning more virtual currency and gaining more stars. The rating number of stars shows great achievements. The higher the star's number rating is, the better its status.
Leader boards	A visual representation of the participant's progression with respect to others. The leader boards exploit social emotions such as feelings of "fame" and "status" while allowing comparison between participants and enhancing competition among them.
Competition	Competition modes are: single-player competition against the game environment; competition between two or more players; cooperation of two or more players against the game environment; and team-based competition. The EMOCASH game supports the first two modes.
Points	Game points are like grades in the educational system. It is a numerical representation of the player's performance in achieving goals. Points are assigned to each activity as a function of the number of goals reached and the time needed to be finished. Each mini-game mode assigns different points to participants. Points can be divided into levels, and levels can be presented with badges.
Badges	Badges are virtual goods that have a visual representation. They are awarded to participants after completing certain challenges or reaching certain achievements. In the EMOCASH game, we used it to represent participants' status or reputation.
Levels	Levels can have different meanings in games. Levels can refer to the rating of the participant based on his/her score or can be related to the difficulty of the game. The EMOCASH game supports both. In terms of difficulty, each mini-game has two levels of difficulty, namely basic and advanced, where the level of complexity increases very gradually in order to keep the participants motivated and to provide them with a continuous challenge (see figures below).

	  
Flow state	To feel the fun, users have to be in the channel of flow state. The flow theory is widely accepted to be one of the fundamental models for improving the game experience. When an individual experiences flow, they are said to be in a "flow state."
Feedback	For generating the flow it is important that activities provide immediate and clear feedback which can be provided with the help of visual and audio elements. As a demonstration, the figure below shows the feedback provided for money comparison and counting mini-game scenarios.   
Progress bar	A progress bar was utilized to graphically represent the proportion of completed tasks in order to display the participants' progress for each activity. For each activity, a green color will emerge if the exercise is successfully solved, signifying that the participant has given the correct response; otherwise, a red one will be displayed.
Progression	Player growth and development.
Visual Aesthetics	Include visual elements such as the overall look and feel of the game.
Game Mechanics	The procedures and rules of the game.
Story	The series of events that occur as players play the game.
Technology	It is the medium through which the tale will be told, the mechanics will occur, and the visual aesthetics will take place. We used intelligent agent technology through online gaming for the EMOCASH game. Moreover, the learning environment was designed using the Autism ASPECTSS™ Design Index to adapt to the needs of all types of users
Game Fantasy	Refers to the environmental contexts that provide virtual world imagery
Sensation	Multimedia presentation of the virtual world.
Emotions	Games are good for creating emotions among participants. Those emotions can be created through gameplay, storytelling, or socialization. The EMOCASH game is a multi-player SG which supports both emotions and socialization among participants.
Avatars	A visual representation of a player character. The EMOCASH game uses anthropomorphic agents in the form of 3D models of rabbits grafted with real faces.

VI. System Development and Implementation

A. System Architectural Design

Architectural design defines the interconnection and resource interfaces between system subsystems components and modules in ways suitable for their detailed design and overall configuration management. As training requires repetitive tasks, having a large number of mini-games is quite important to avoid boredom in the long term. Fig. 12 shows a sample architectural design overview of our EMOCASH game architecture, which is composed of six 3D mini-games, each one with two difficulty levels (basic and advanced). The complete navigational system for the EMOCASH game is shown in Fig. 13.

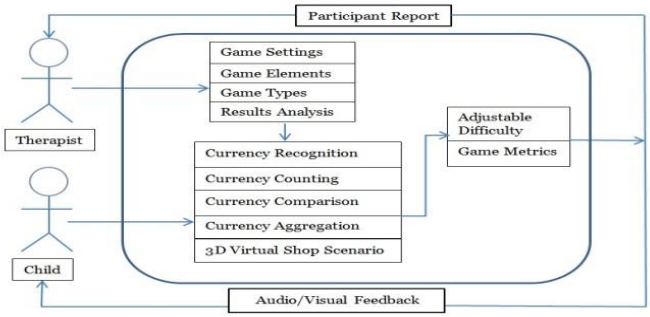


Fig. 12. EMOCASH's system architecture.

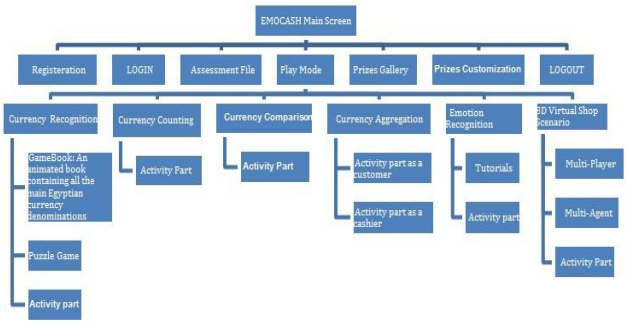


Fig. 13. EMOCASH's system navigation scheme.

B. *Learning Mechanics-Game Mechanics (LM-GM) Model for EMOCASH Gameplay*

This subsection analyzes the relevance of learning mechanics and game mechanics for the EMOCASH gameplay through the Learning Mechanics-Game Mechanics mapping model (LM-GM) [65]. Several authors have offered definitions of the idea of game mechanics. However, there are no universally agreed-upon definitions of game mechanics, as evidenced by the wealth of literature [66]-[68]. For instance, game mechanics are described as "something that connects the player's actions with the purpose of the game and its main challenges" in a definition offered by [68]. On the other hand, activities or design patterns of mechanics that explicitly support learning but are not playable mechanics are referred to as learning mechanics. Table II displays the analysis of both the learning and game mechanics for the EMOCASH gameplay through the LM-GM model [65], [66], as well as how participants use them and how they were actually implemented.

TABLE II. THE LM-GM MODEL ANALYSIS FOR THE EMOCASH GAMEPLAY

Game Mechanics	Learning Mechanics	Implementation	Usage/Description
Cascading information/ Tutorials	Guidance/ Tutorial	The main goals and regulations of each mini-game are explained at the start of the introduction to the entire EMOCASH game with the help of a brief animation and voice.	Main goals are clearly presented in the game's introduction to keep participants' attention and ensure that they will be able to comprehend the necessary tasks.
Cooperation/ Collaboration	Emotion/ Competition/ Participation	The gaming environment in the EMOCASH game is designed as a 3D virtual shop scenario using the Autism ASPECTSS™ Design Index and is based on the idea of authentic learning with authentic tasks, such as shopping at the supermarket.	Games are good for creating emotions among participants. Those emotions can be created through gameplay, or socialization. Using a CVLE, the EMOCASH game is a multi-player SG which supports both emotions and socialization among participants.
Time pressure	Motivation Action/Task	Count down clocks/Response time	Extrinsic motivation.
Meta-Game Mechanic (Rewards that can be earned during the actual gameplay)/ Collecting (Elements of virtual rewards can be represented by virtual objects, which can be collected by the player)	Motivation/ Rewards/ Incentive	All six types of 3D mini-game engines include this feature.	The player earns virtual currency with a numeric value and some stars for each correct answer and for each mini-game successfully completed in the entire game.
Questions & Answers	Assessment	Once the player finishes practicing the currency recognition mini-game, he or she will have to play two simple and fun quiz games called puzzle and matching games before proceeding to the next task.	All five types of 3D mini-game engines include an activity part with two levels of difficulty, namely, basic and advanced, where the level of complexity increases very gradually in order to keep the participants motivated and provide them with a continuous challenge.
Rewards	Motivation/ Instructional/ Feedback	Extrinsic rewards, such as points, badges, and leader boards, are available through EMOCASH, as well as intrinsic rewards, which are given for successfully completing each mini-game throughout the entire game in exchange for resources (such as earning virtual currency with a numeric value) and reputation (such as a certain number of stars).	Extrinsic and intrinsic rewards are used to keep participants engaged in SGs and keep them happy and satisfied.
Behavioral momentum	Incentive/ Motivation/ Participation	The virtual gained items from the prize gallery are stored in an inventory which can be reached by clicking on the "prizes customization" button on the main screen to enable the participants to experience a personalized training by meeting their curiosity and virtually using the items through a variety of customization options.	It is a fun feature that motivates the participants during the game.
Feedback	Motivation/ Feedback	Points/levels/response time//badges/ emotional sounds/ audio-visual feedback/Progress bar.	Extrinsic rewards that facilitate both motivation and flow state.
Capture (How many points or counters a player has won or captured	Action/Task Participation	Stars earned and the score of each mini-game completed.	Use information to solve problems. The accomplishment of goals during gaming is represented by stars, which are gathered with each new goal attained. The rating number of

defines how strong they are)			stars shows great achievements.
Challenge	Questions & Answers/ Action/Task /Participation/ Feedback/ Assessment	▪ Challenges in games must match the player's skill level ▪ Games should provide different levels of challenge for different players ▪ The level of challenge should increase as the player progresses through the game	Challenges are game tasks or exercises that require effort to perform. In the EMOCASH game, there are a lot of tasks for each mini-game to be completed. Once achieved, some rewards are provided. For instance, in the case of a puzzle game, the main challenge is the participant's ability to piece together the required image using the materials they have collected from a variable number of pieces that are spread out across a table surface in random placements.

C. Implementation

Our system is organized in multiple levels and implemented using Unity. Blender software was used to create the learning environment as well as the 3D models of various objects (e.g., rabbits) and import them into Unity. Since different currencies have a range of different coin values, or denominations, we employed the greedy change algorithm [69] in our implementation of the change problem.

VII. Method

A. Participants

In this study, we recruited a sample of fourteen distinct autistic children between the ages of seven and fifteen to play the EMOCASH game for at least one and a half hours each week, for a total of seven weeks of open trial. These groups, referred to as "Group #1," received an autism diagnosis from a psychiatrist and a clinical psychologist. Ten children (72%) were boys, while four (28%) were girls. We also invited a group of seven typically developing volunteer children, referred to as "Group#2," who tested the game in order to measure the effectiveness of using the developed application. Ethical approval was granted by the Egyptian General Ethics Standards.

B. Procedure and Materials

The intervention protocol used for participants consists of three different phases: pre-intervention, intervention, and post-intervention phases. During pre-intervention sessions, children completed IQ testing representing verbal and performance IQ taken from the 2nd Wechsler Abbreviated Scale of Intelligence **(**WASI- II**),** and parents filled out the Social Responsiveness Scale, 2nd edition (SRS-2) and the Vineland Adaptive Behavior Scales, 2nd edition (VABS-II) to confirm the children's diagnostic status. At the end of the pre-intervention session, participants and their parents were introduced to the EMOCASH game. A seven-week, three-times-per-week EMOCASH training program was part of the participant's intervention procedure. After a 7-week intervention period, participants and their parents participated in the post-intervention assessment. In this phase, a questionnaire is created to assess the expectations and satisfaction of both parents and children playing EMOCASH game.

VIII. Evaluation, Usability Testing and Results

A. Usability Testing with Experts

Usability testing is a technique used to assess the effectiveness and satisfaction of a developed application by its users and experts. Four subject-matter experts in different fields were asked to participate; two of them were experts in psychology and psychiatry, while the other two were experts in game design and teaching, respectively. Furthermore, to identify the usability issues of the developed application in terms of efficiency and satisfaction, it was evaluated not only from the experts' perspective but also with input from people who are not disabled (Group#2). The purpose of these tests serves the function of gathering system feedback. A list of the six mini-games engine's interface and the tasks to be carried out in the EMOCASH game were given to the experts for usability analysis to be sure that it is suitable for use by children with ASD without any issues. Five themes were used to group the perspectives of experts on the EMOCASH gameplay: Effectiveness, usefulness, enjoyment, ease of use, and attitudes toward future usage. Most experts agreed that the proposed game was effective because of the following factors: (1) goals were clearly presented in the game's introduction to the entire EMOCASH game with the help of a brief animation and voice, which improve attention and help with their learning; (2) the presentation of multimedia resources (audio, visual, etc.) is done simultaneously; (3) immediate and clear feedback was given with the help of multimedia resources; (4) clear goals and feedback support concentration, which is one of the learning outcomes; (5) learner activities that use authentic learning closely resemble the real-world situations that professionals encounter while practicing; and (6) promoting practical life skills like money management can enhance a person's autonomy and self-determination. According to experts in the psychology and psychiatric disciplines, the game is useful since it is affordable, promotes self-confidence, may aid with motor skill development, and saves time for the teachers. Experts in game design and teaching fields found that the game is enjoyable because of the following reasons: (1) it attempts to increase both participant concentration and the sense of curiosity in individuals with ASD; (2) it contains audio-visual feedback and both extrinsic (e.g., points, badges, leader boards, etc.) and intrinsic rewards that facilitate motivation and flow state and, as a result, promote players' engagement, learning, and motivational outcomes; and (3) playing online games, which improve the user's experience, immersion, foster social engagement and competition, and reduce autistic symptoms, increases the enjoyment of working independently. In terms of usability, the majority of experts agreed that the game is useful, easy to use, and user-friendly, and that the challenge-skill balance matches the player's skill level. In addition, they reported that the game's mechanics and interface are straightforward, simple to understand, and non-intrusive, allowing for simple access to the game. In terms of attitude, all experts agreed that the game could be objectively used as a teaching tool for treating children with ASD in a cost-effective manner. They also found that the game is enjoyable, fascinating, and beneficial.

B. Evaluation Instrument for User Satisfaction

To evaluate the functionality of the system we have distributed a questionnaire evaluation form to assess expectations and satisfaction among parents and their children. Parents rated their expectations and satisfaction by filling out several questionnaires using a 10-point Likert scale to during pre-intervention and post-intervention measurement. Sample questionnaires are given in Table III.

TABLE III. A SAMPLE ASSESSMENT QUESTIONNAIRE FOR PARENT EXPECTATIONS AND SATISFACTION

Q#1	Parent expectations sample questionnaire	Parent satisfaction sample questionnaire
1	Do you think that this EMOCASH game is educational for your child?	How motivated was your child to play the EMOCASH game?
2	How much do you expect your child's skills will advance after playing the EMOCASH game?	Do you think the EMOCASH game had an effect on your child's performance on the different daily living (DL) tasks/skills?

After finishing the EMOCASH game, participants were also asked to provide their opinions, including what they enjoyed and disliked about it, as well as their favorite game. For this purpose, we utilized the Fun Toolkit [70], to assess participants' satisfaction. Moreover, all experts and ordinary volunteer children answered the System Usability Scale (SUS) questionnaire [71] after playing the game. The SUS questionnaire contains 10 questions about ease of learning, efficiency, ease of memorization, occurrence of execution errors, and level of satisfaction. Each question has a five-point scale varies from one (totally disagree) to five (totally agree). By combining the contributions of the scores of each item, the SUS questionnaire's results were analyzed. The results were positive between experts and ordinary volunteer children regarding their acceptance.

C. Game Data and Usability Metrics

The EMOCASH game's usability was assessed using the game data of each participant. The data for the game is stored in internal structures and contains the participant's score for each game successfully completed. The system creates reports in the assessment file folder when the participant has finished the games, providing the therapist with feedback. In order to test the application with users and to measure the efficiency and effectiveness of the application's use in education, we considered the following usability metrics [72] (see Fig. 14) where,

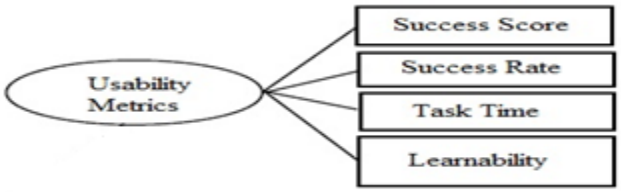


Fig. 14. Usability metrics.

1) Success Score: It refers to whether the user accomplished or didn't finish the required task (Number of completed tasks/Total number of attempts).

2) Success Rate. This includes several levels of success: a) Complete success: the user completed the task with no errors and exactly as specified; b) Minor issue success: the user completed the task but encountered a minor issue; c) Major issue success: the user completed the task but encountered a major issue; and d) Failure: the user was unable to complete or finish the required task.

3) Task Time: The amount of time it takes the user to complete the task.

4) Learnability Rate: it takes into account both how simple a task is for users to perform the first time they use the interface and how many tries it takes for them to get it right. Fig. 15 depicts the learnability rate for the participants' responses using conventional and non- conventional ways after practice with our EMOCASH game. It is clear that after practicing with our game, their performance improved significantly.

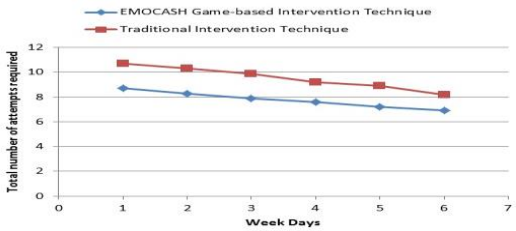


Fig. 15. Learnability rate.

D. Results and Discussion

This section describes the findings of the responses collected from experts, parents, and their children. This was done to help children recognize the EMOCASH game as a learning tool and determine which features of the game are more attractive. The results of the collected data show that the game is very useful and the results are given as follows:

- Most of them agreed that the system is helpful, straightforward to use with a user-friendly learning environment, and has simple content with good topic flow.
- Regarding game motivation, most of the participants found the game to be fun to play, especially when applying newly learned information through the 3D virtual store setting, which fosters feelings and sociability among players who can play alone or with their educators.
- Concerning game usability, most of the participants were able to play the game because their preferences were achieved via factors like simple GUI, audio-visual feedback, and both extrinsic and intrinsic rewards. Most experts rated the usability of the EMOCASH game as "excellent"
- The majority of the experts, typical volunteer children, as well as parents and their children with ASD, were satisfied with the EMOCASH game. Experts indicate that the game appears to have outstanding potential and can be objectively used as a teaching aid for assisting individuals with ASD. Parents also reported that seven

weeks of EMOCASH's use significantly improved their children's performance on the different money and emotion recognition tasks.

- The gathered data also explores the beneficial effects of involvement in online gaming as an effective teaching strategy for those with ASD. People with ASD can communicate more easily and participate in the gaming community without having to disclose their handicap by playing online games.

E. Comparisons

According to the taxonomy discussed in [46], [47], Table IV compares our proposed framework (EMOCASH) with other existing frameworks previously discussed during this research. As demonstrated in Table IV, all of the prior research only took into account a single player in a two dimensional gaming world, as opposed to multi-player collaborative games in three dimensions, which support both emotions and social interaction among participants and facilitate collaborative learning, which are more motivating and engaging than a single one. In addition, this research is one of the few that uses authentic learning activities like going shopping while adhering to the autism ASPECTSS™ Design Index, a set of architectural design guidelines for individuals with autism. The EMOCASH game possesses the following merits that set it apart from previous works: (1) the scenario uses a CALE, which supports multiplayer, which is more engaging and motivating than single-player training games; (2) the sensory environment issues and their relationship to autistic behavior were taken into consideration by applying the Autism ASPECTSS™ Design Index as a design development tool for the EMOCASH game's environment to adapt to the needs of all types of users; (3) it explores the beneficial effects of involvement in online gaming as an effective teaching strategy for those with ASD; (4) our strategy takes into account the wide range of game elements and attributes to enhance training outcomes while keeping participant motivation; (5) the learning mechanics-game mechanics (LM-GM) model idea was used to assess and examine the efficacy of the proposed game in order to keep participants' interest and motivation; and (6) the game was developed using a number of design principles, such as guidelines from the literature, guidance from learning experts and instructors, and feedback from a wide range of stakeholders, including those who are not impaired.

TABLE IV. COMPARISON BETWEEN OUR PROPOSED FRAMEWORK AND THE OTHER EXISTING FRAMEWORKS

Criteria	Sources/References										
	EMOCASH	[5]	[7]	[6]	[4]	[42]	[41]	[40]	[43]	[44]	[39]
Learning Topics	Conceptual and social skills	Conceptual skills	Conceptual skills	Conceptual skills	Conceptual skills	Social skills	Social skills	Social skills	Social skills	Social skills	Social skills
Learning Objectives	Learning money & emotion recognition	Learning how to manage money	Learning money concept	Learning how to manage money	Learning how to manage money	Learning Emotion Recognition (LER)	LER	LER	LER	LER	LER
Game Interface	3D	2D	2D	2D	2D	2D	2D	3D	3D	2D	2D
Target Audience	Autistic disorder	High-Functioning ASD (High-F-ASD)	Autistic children	Intellectual disability	Cognitive impairments	Autistic children (AC)	Autistic children (AC)	AC	High-F-ASD	Autistic children (AC)	Autistic children (AC)
Interaction Style	Traditional-IO (T-IO)	T-IO	T-IO	T-IO	T-IO	T-IO	T-IO	T-IO	T-IO	T-IO	T-IO
Feedback	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Progress monitoring	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of players	Single/ Multi-player	Single player	Single player	Single player	Single player	Single player	Single player	Single player	Single player	Single player	Single player
Collaborative learning	Yes	No	No	No	No	No	No	No	No	No	No
Social Presence	Yes	No	No	No	No	No	No	No	No	No	No
Sensory Environment Design Issues	Yes	No	No	No	No	No	No	No	No	No	No
Game portability	Home/ Hospital	Home	Home	Home	Home	Home/ Hospital	Home	Home/ Hospital	Hospital	Home/ Hospital	Home/ Hospital
Usability Testing	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Knowledge Transfer to	Yes, via 3-D Virtual	Yes, through an	No	No	Yes, via a Simplified	No	No	No	No	No	No

Real-world Scenarios	Shop Scenario	Interaction with a Vending Machine (using coins only).			Cash Accounting.						

IX. Conclusion and Future Work

The number of people with ASD continues to grow worldwide. As a result of the incapacity symptoms, they often experience serious difficulties in performing daily living activities independently. Money management and recognizing emotions are two essential daily living activities that people with ASD generally struggle with. When designing a learning environment for them, care should be taken to take into account any sensory challenges they may have. The problem of the sensory environment and its connection to autistic behavior seems to be the key to designing for autism. There are few studies that look at sensory design issues while developing children's learning environments, and there is a noticeable lack of studies on how using virtual environments and playing online games affects social and relational interactions for persons with ASD. This paper addresses these issues and makes an effort to close this gap using a novel virtual agent-based multiplayer online serious game called "EMOCASH," which aims to enhance these crucial tasks for Egyptian children with ASD and achieve transfer of learned skills to real-world contexts via a 3D virtual shop scenario created using the Autism ASPECTSS^{TM} Design Index. EMOCASH served as an instrumental tool for investigating numerous relevant research questions. A variety of usability metrics, were used to assess effectiveness, efficiency, and satisfaction aspects. This study is one of the few implementing activities related to real-world scenarios, such as shopping in the supermarket for people with autism using intelligent agent technology through online gaming. Our findings indicate that, when compared to non-agent methods, virtual agent technology through online gaming, reinforced by sensory design aspects, may be used as an objectively successful learning technique for individuals with ASD. Our future work will focus on three directions: 1) expanding the number of activities developed and making the application available on various platforms; 2) analyzing the impact on larger populations of autistic children with various categories; and 3) employing Brain-Computer Interface technology as a physiological measuring instrument that retrieves and uses information about an individual's mental state, which is closely related to the ToM and anthropomorphism.

Acknowledgment

The author appreciates the help and insightful conversation he received from Eng. Islam Abd El-Sattar, Mr. Mohamed Abdullah, and Mr. Yousef Salah.

References

[1] Nikou, S. A. and Economides, A. (2021). A Framework for Mobile-Assisted Formative Assessment to Promote Students' Self-Determination. Future Internet. 13. 116. 10.3390/fi13050116.

[2] Yeni, S., Cagiltay, K. and Karasu, N., (2020). Usability investigation of an educational mobile application for individuals with intellectual disabilities. Universal Access in the Information Society, 19:619–632, https://doi.org/10.1007/s10209-019-00655-0

[3] Urturi, Z.S., Zorrilla, A.M., and Zapirain, B.G. (2012). A Serious Game for Android Devices to Help Educate Individuals with Autism on Basic First Aid. In: Omatu, S., Depaz Santana, J., Gonzalez, S., Molina, J., Bernardos, A., Rodriguez, J. (eds) Distributed Computing and AI. Advances in Intelligent and Soft Computing, Vol. 151, Springer, Berlin, Heidellberg. DOI: 10.1007/978-3-642-28765-7_74

[4] Abdel Wahed, Shiruk et. al. (2020). QUALY: A Money Management Application for People with Cognitive Impairments. 14th International Conference on Game Based Learning ECGBL 2020, 10.34190/GBL.20.109

[5] Caria, S., Paternò, F., Santoro, C. and Semucci, V. (2018). The Design of Web games for helping young High-Functioning Autistics in learning how to manage money. Mob. Netw. Vol. 23, pp. 1735–1748

[6] Lopez-Basterretxea, A., Mendez-Zorrilla, A. and Garcia-Zapirain, B. (2014). Telemonitoring Tool based on Serious Games Addressing Money Management Skills for People with Intellectual Disability. Int. J. Environ. Res. Public Health, Vol. 11, pp. 2361-2380, doi:10.3390/ijerph11030236

[7] Arshia Z. H., Bushra, T. Z., Fatema T. Z., Johra M., Tasmiha Md. Mustafizur R., Hasan S. F., Syed , I. A. (2011). Developing the concept of money by interactive computer games for autistic children. In Conf. Rec. 2011 IEEE Int. Symposium on Multimedia, pp. 559–564

[8] Nur Syaheera, B. S., Hamzah Asyrani, B. S., Nor Saradatul Akmar, B. Z., & Tuty Asmawanty, B. A. (2023). MMZ: A study on the implementation of mathematical game-based learning tool. International Journal of Advanced Computer Science and Applications, Vol. 14 (1).

[9] Ayman A., Hind B., Mayda, A., Hind, A., & Eman, S., (2021). DoItRight: An Arabic gamified mobile application to raise awareness about the effect of littering among children. International Journal of Advanced Computer Science and Applications, Vol. 12, No. 12.

[10] Moosa, A. M. et. al. (2020). Designing a mobile serious game for raising awareness of diabetic children. IEEE Access, DOI: 0.1109/ACCESS.2020.3043840

[11] Karolina, D. Kamil, D., Lucci, R. B., and Anita, B. (2020). Therapeutic programs aimed at developing the theory of mind in patients with autism spectrum disorders – available methods and their effectiveness. Psychiatria Pol. Vol. 54, No. 3, pp. 591–602, doi: https://doi.org/10.12740/PP/108493.

[12] Rosello, B., Berenguer, C., Baixauli, I., García, R., and Miranda, A. (2020). Theory of Mind Profiles in Children with Autism Spectrum Disorder: Adaptive/Social Skills and Pragmatic Competence. Frontiers in Psychology, Vol. 11, doi:10.3389/fpsyg.2020.567401.

[13] Roberto, M., Claudio, M., Rodolfo, V., Angeles, Q., and Victor Hugo, C. D. (2019). Developing a software that supports the improvement of the Theory of Mind in Children with ASD. IEEE Access, doi: 10.1109/ACCESS.2018.2890220.

[14] Baron-Cohen, S. (2014). Theory of mind and autism: A review. International Review of Research in Mental Retardation, vol. 23

[15] Ruud, H., Michaela, K., Kohinoor, M. D., Laura, J., Kami, K., Richard, R. and Emily, S. C. (2021). Exploring the relationship between anthropomorphism and Theory-of-Mind in brain and behavior. Human Brain Mapping, vol. 42, pp. 4224–4241, doi: 10.1002/hbm.25542

[16] Atherton, G. and Cross, L. (2018). Seeing more than human: Autism and anthropomorphic theory of mind. Frontiers in Psychology. vol. 9, no. 528, pp. 1–18, doi: 10.3389/fpsyg.2018.00528

[17] Liam, C., Myles, F. and Gray, A.(2019). The Animal in Me: Enhancing Emotion Recognition in Adolescents with Autism Using Animal Filters. Journal of Autism and Dev. Disorders, vol. 49, pp. 4482–4487, https://doi.org/10.1007/s10803-019-04179-7

[18] Atherton, G. and Cross, L. (2019). Animal faux pas: Two legs good four legs bad for theo-ry of mind, but not in the broad autism spectrum. *The Journal of Genetic Psychology*, 180(2–3), pp. 81–95, https://doi.org/10.1080/00221 325.2019.15931 00 .

[19] Whyte, E. M., Behrmann, M., Minshew, N. J., Garcia, N. V., and Scherf, K. S. (2016). Animal, but not human, faces engage the distributed face network in adolescents with autism. Developmental Science, vol. 19, no. 2, pp. 306–317

[20] O'Haire ME., McKenzie, SJ. Beck, AM. and Slaughter, V. (2013). Social Behaviors Increase in Children with Autism in the Presence of Animals Compared to Toys. PLoS ONE 8(2): e57010, doi:10.1371/journal.pone.0057010

[21] Golan, O., Ashwin, E., Granader, Y., McClintock, S., Kate, D., Victoria, L. and Baron-Cohen, S. (2010). Enhancing emotion recognition in children with Autism Spectrum Conditions: an intervention using animated vehicles with real emotional faces. Journal of Autism and Developmental Disorders, vol. 40, pp. 269-279

[22] Mostafa, M., (2015). Architecture for Autism: Built Environment Performance in Accordance to the Autism ASPECTSS™ Design Index. Design Principles and Practices: an International Journal Annual Review, 8 (1): 55- 71. doi:10.18848/1833-1874/CGP/v08/38300

[23] Hussein, K., (2023). Towards smart authentic learning environment using IT through online gaming for promoting money management skills in Egyptian children with autism. Submitted for publication.

[24] Almurashi, H., Bouaziz, H., Alharthi, R., Al-Sarem, W., Hadwan, M., and Kammoun, S. (2022). Augmented Reality, Serious Games and Picture Exchange Communication System for People with ASD: Systematic Literature Review and Future Directions. Sensors, vol. 22, https:// doi.org/10.3390/s22031250

[25] Petersen, G., Petkakis, G. and Makransky, G. (2022). A study of how immersion and interactivity drive VR learning. Computers & Education, Vol. 179, https://doi.org/10.1016/j.compedu.2021.104429.

[26] Desideri, L., Pérez-Fuster, P. and Herrera, G. (2021). Information and Communication Technologies to Support Early Screening of Autism Spectrum Disorder: A Systematic Review. Children, Vol. 8, No. 93, https://doi.org/10.3390/ children8020093.

[27] Zhang, K. and Aslan, A. B. (2021). AI technologies for education: Recent research & future directions. Computers and Education: Artificial Intelligence, Vol. 2, https://doi.org/10.1016/j.caeai.2021.100025.

[28] Abu-Amara, F., Bensefia, A., Mohammad, H. and Tamimi, H. (2021). Robot and virtual reality-based intervention in autism: a comprehensive review. Int. J. Inf. Tecnol., Vol. 13, No. 5, pp. 1879–1891 https://doi.org/10.1007/s41870-021-00740-9.

[29] Pérez-Fuster, P., Sevilla, J. and Herrera, G. (2019). Enhancing daily living skills in four adults with autism spectrum disorder through an embodied digital technology-mediated intervention. Res. Autism Spectrum Disorder, Vol. 58, pp. 54–67.

[30] Valencia, K., Rusu, C., Daniela, Q. and Erick, J. (2019). The Impact of Technology on People with Autism Spectrum Disorder: A Systematic Literature Review. Sensors, doi: 10.3390/s19204485

[31] Raith L, Bignill J, Stavropoulos V, Millear P, Allen A, Stallman HM, Mason J, De Regt T, Wood A and Kannis-Dymand L. (2022). Massively Multiplayer Online Games and Well-Being: A Systematic Literature Review. Front. Psychol. 12:698799, (2022), doi: 10.3389/fpsyg.2021.698799

[32] Mikhailova, O. B. (2019). High school students involved and not involved in MMORPG: creativity and innovativeness. International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE), 7(2), 29-39.

[33] Gallup, J., Serianni, B., Duff, C., & Gallup, A. (2016). An exploration of friendships and socialization for adolescents with autism engaged in massive multiplayer online role-playing games (MMORPG). Education and Training in Autism and Developmental Disabilities, 51(3), 223-237

[34] Zhang, Y., Song, H., Liu, X., Tang, D., & Chen, Y. (2017). Language learning enhanced by massive multiple online role-playing games (MMORPGs) and the underlying behavioral and neural mechanisms. Frontiers in Human Neuroscience. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5332359

[35] Lombardi, M. (2007). Authentic learning for the 21st century: An overview. Ed. By Oblinger, D. ELI Paper 1: EDUCAUSE Learning Initiative. https://net.educause.edu/ir/library/pdf/ELI3009.pdf.

[36] Nicaise, M, Gibney, T, & Crane, M. (2000). Toward an understanding of authentic learning: Student Perceptions of an Authentic Classroom. Journal of Science Education and Technology, vol. 9, no. 1, pp. 79-94, https://doi.org/10.1023/A:1009477008671

[37] Koh, J.H.L., Chai, C.S., Wong, B., Hong, HY. (2015). Design Thinking and 21st Century Skills. In: Design thinking for education, Chapter#3. Springer, Singapore, https://doi.org/10.1007/978-981287-444-3_3

[38] Noel, K.H.C. & Saranya, E. (2015). Authentic Design Thinking for Special Education Teachers: Two Case Studies with a Special Focus on Autism. Journal of humanities and social science (IOSR-JHSS), Vol. 20 (3). Doi:10.6084/M9.FIGSHARE.1353821.V1

[39] Leandro, M. A. et al. (2019). ALTRIRAS: A Computer Game for Training Children with Autism Spectrum Disorder in the Recognition of Basic Emotions. International Journal of Computer Games Technology, Volume 2019, https://doi.org/10.1155/2019/4384896.

[40] Grossard, C. et al. (2019). Teaching Facial Expression Production in Autism: The Serious Game JEMImE. Creative Education, Vol. 10.

[41] Min, F., Alissa, N. A., Jianyu, F., Philippe, A., and Sheng, J. (2018). EmoStory: A Game-based System Supporting Children's Emotional Development. Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems, 2018, https://doi.org/10.1145/3170427.3188594.

[42] Fridenson-Hayo, S. et. al. (2017). Emotiplay: a serious game for learning about emotions in children with autism: results of a cross-cultural evaluation. European Child and Adolescent Psychiatry, Vol. 26, No. 8, pp. 979-992, doi: 10.1007/s00787-017-0968-0.

[43] Serret, S., et al. (2014). Facing the challenge of teaching emotions to individuals with low- and high-functioning autism using a new serious game: a pilot study. Molecular Autism, Vol. 5, No. 37.

[44] Alves, S., Marques, A., Queirós, C. and Orvalho, V., (2013). LIFEisGAME prototype: A serious game about emotions for children with autism spectrum disorders. PsychNology Journal, *11*(3), 191–21.

[45] Yan, Y. Liu, C., Ye, L. and Liu, Y. (2018). Using animated vehicles with real emotional faces to improve emotion recognition in Chinese children with autism spectrum disorder. PLoS ONE, Vol. 13,No. 7.

[46] Fedwa, L., Mohamad, E., and El Sadik A., (2014). An Overview of Serious Games. Int. Journal of Computer Games Technology, vol. 2014, pp.1-15.

[47] Plass, J., Homer, D., and Kinze, K., (2015). Foundations of Game-Based Learning. Educational Psychologist, Vol. 50, No. 4, pp. 258–283.

[48] Nikou, S.A., (2023). Student motivation and engagment in maker activities under the lens of the activity theory: A case study in a primary school. J. Comput. Educ., https://doi.org/10.1007/s40692-023-00258-y00258-y

[49] Hasan, H. & A. Kazlauskas, A., (2014). Activity Theory: who is doing what, why and how?," In H. Hasan (Eds.), Being practical with theory: A Window into Business Research, Wollongong, Australia: THEORI, 2014.

[50] Rajendran, G. (2013). Virtual environments and autism: a developmental psychopathological approach, Journal of Computer Assisted Learning, 29, 334–347.

[51] Fox, J., Beveridge, B. M. and Glasspool, D. W. (2003). Understanding intelligent agents: Analysis and Synthesis. AI Communications, vol. 16, no. 3, pp 139–152.

[52] Russell S. and Norvig, P. (2010). Artificial Intelligence: A Modern Approach. Prentice-Hall.

[53] Cayubit, R.F.O. (2022). Why learning environment matters? An analysis on how the learning environment influences the academic motivation, learning strategies and engagement of college students. Learning Environments Research 25, 581-599, https://doi.org/10.1007/s10984021-09382-x.

[54] Ghazali, R., Md. Sakip, S. R., & Samsuddin, I. (2018). The Effects of Sensory Design on Autistic Children. Asian Journal of Behavioural Studies, *3*(14), 68–83. https://doi.org/10.21834/ajbes.v3i14.165

[55] Dehkordi, S. R., Ismail, M., & Diah, N. M. (2022). Game-Based Learning Application for Children with Autism Spectrum Disorder using Participatory Design. International Journal of Academic Research in Progressive Education and Development, 11(1), 1-13

[56] Kim, Y. and Baylor, A. L.(2016). Research-based design of pedagogical agent roles: A review, progress, and recommendations. Int. J. Artif. Intell. Educ. Vol. 26, 160–169, doi: 10.1007/s40593-015-0055-y.

[57] Schroeder, N. L., Romine, W. L. & Craig, S. D. (2017). Measuring pedagogical agent persona and the influence of agent persona on learning. Comput. Educ., vol. 109, pp. 176–186, doi:10.1016/j.compedu.2017.02.015

[58] Neelu Jyothi, A. et al. (2022). Investigative Study on the Effects of Pedagogical Agents on Intrinsic, Extraneous and Germane Cognitive Load: Experimental Findings With Dyscalculia and Non-Dyscalculia Learners, IEEE Access, DOI: 0.1109/ACCESS.2021.3115409.

[59] Armando, M., Ochs, M. & Régner, I. (2022). The Impact of Pedagogical Agents' Gender on Academic Learning: A Systematic Review. Front. Artif. Intell. 5:862997, doi: 10.3389/frai.2022.862997

[60] Johnson, W., & Lester, J. C. (2015). Face-to-Face Interaction with Pedagogical Agents, Twenty Years Later. International Journal of Artificial Intelligence in Education, vol. 2

[61] Lutami, P. S., Athallah, F. R., Nur Huda, Y. & Zain, F. D. (2022). A Review of Pathfinding in Game Development. Journal of Computer Engineering: Progress, Application and Technology, vol 1, pp. 47-56**.**

[62] Janet T. et al. (2022). Games and Rewards: A Scientometric Study of rewards in Educational and Serious Games, IEEE Access.

[63] Chen, J., Wang, G., Zhang, K., Wang, G. and Liu, L. (2019). A pilot study on evaluating children with autism spectrum disorder using computer games. Comput. Hum. Behav., pp. 204–214.

[64] Hamari, J., Koivisto, J. and Sarsa, H. (2014). Does Gamification Work? A Literature Review of Empirical Studies on Gamification. In 2014 47th Hawaii Int. Conf. on System Sciences (pp. 3025–3034). IEEE. doi:10.1109/HICSS.2014.377.

[65] Lim, T., Louchart, S., Suttie, N. et al., (2013). Strategies for effective digital games development and implementation. In Y. Baek & N. Whitton (Eds.), Cases on digital game-based learning: methods, models, and strategies (pp. 168–198). Hershey, PA, USA: IGI Global.

[66] Arnab, S. Lim, T., Carvalho, M. B. et al. (2015). Mapping learning and game mechanics for serious games analysis: Mapping learning and game mechanics. British Journal of Educational Technology, Vol. 46, No. 2, pp. 391–411. http://doi.org/10.1111/bjet.12113

[67] Salen K. and Zimmerman, E. (2010). Rules of play: Game design fundamentals. Cambridge, MA: The MIT Press, 2010

[68] Sicart, M. (2008). Designing game mechanics. International Journal of Computer Game Research, Vol. 8, No. 2

[69] Phillip E. C. Compeau and Pavel A. Pevzner, (2018). Bioinformatics Algorithms: An Active Learning Approach. 3rd edition, ISBN:978-0-9903746-3-3, Active Learning Publishers

[70] Gavin, S. & Matthew H., (2012). Investigating Children's Opinions of Games: Fun Toolkit vs. This or That. Proc. of the 11th international Conf. on Interaction Design and Children, pp. 70-77. https://doi.org/10.1145/2307096.2307105

[71] McLellan, S., Muddimer, A. & Camille, P. S. (2011). The effect of experience on System Usability Scale Ratings. Journal of Usability Studies, vol. 7, no. 2, pp.56-67, 2011

[72] Albert W., & Tullis, T., (2013). Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics (Interactive Technologies). San Mateo, CA, USA: Morgan Kaufmann.