

Technological Educational Institute of Crete

A SERIOUS GAME AS A SCREENING TOOL TO IDENTIFY CHILDREN WITH DYSLEXIA

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Abstract

“Dyslexia is a neurodevelopmental disorder characterized by deficits in the ability to learn or to use specific academic skills. Dyslexia is a cross-cultural and chronic condition that typically persists into adulthood. Early signs of learning difficulties may appear in the preschool years (e.g., difficulty learning names of letters or counting objects), but they can only be diagnosed reliably after starting formal education.” (APA, 2013)

In this thesis, we designed and implemented a serious game as a screening tool in order to identify children at risk for dyslexia at the end of 2nd grade and at the beginning of 3rd grade of primary school. Moreover, we tested Serious Game Screening Tool (SGST) with 2nd grade students. We tracked SGST’s produced data with xAPI standard specification and analyzed them in a Learning Record Store (LRS).

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1. PART A- Theoretical Background

Introduction

Serious Games (SG) are games that do not have entertainment, as their primary purpose. The engaging and motivational aspects of serious games lead many sectors and organizations from business, health, military and education to use SG to support learning and training (Marsh, 2011).

Serious game can produce massive user data. The interactive nature of serious games makes them a good source of Learning Analytics (LA) data. Serious Games Analytics (SGA) focus on the real-time measurement, assessment, and improvement of learning and performance (Laamarti, Eid, & Saddik, 2014).

The Experience Application Programming Interface (xAPI) is a well-known specification for learning technology that makes it possible to collect data about the wide range of experiences a person has online and offline. xAPI is an appropriate standard to represent serious games analytics. (Serrano-Laguna et al., 2017).

Authoring tools are software applications used to develop eLearning products. Adoption to xAPI is almost ubiquitous amongst authoring tool vendors (ADL, 2018). The majority of authoring tools support xAPI specification albeit to varying degrees. Authoring tools can be used to create serious games.

Moreover, “Dyslexia is a neurodevelopmental disorder characterized by deficits in the ability to learn or to use specific academic skills. Dyslexia is a cross-cultural and chronic condition that typically persists into adulthood. Early signs of learning difficulties may appear in the preschool years (e.g., difficulty learning names of letters or counting objects), but they can only be diagnosed reliably after starting formal education” (APA, 2013)

Screening measures, are typically brief assessments of a particular skill or ability that is highly predictive of a later outcome. Screening measures are designed to quickly differentiate students into one of two groups: a) those who require intervention and b) those who do not. A screening measure needs to focus on specific skills that are highly correlated with broader measures of reading achievement resulting in a highly accurate sorting of students (“Dyslexia Screener,” n.d.).

In this research- thesis, we analyzed, designed and implemented a serious game as a screening tool to identify children at risk for dyslexia at the end of 2nd grade and at the beginning of 3rd grade of primary school.

We tested the Serious Game Screening Tool (SGST) with 2nd grade students. Furthermore, we tracked SGST’s produced data with xAPI standard specification and analyzed them in Learning locker’s Learning Record Store (LRS) (“Learning Locker,” n.d.) .

This thesis is organized as follows. In part A, we are reviewing the literature on Serious Games, Serious Games Analytics, xAPI specification, Authoring Tools and Dyslexia.

In part B, we are analyzing the Serious Game Screening Tool (SGST) (design and implementation), the structure of the Learning Record Store (LRS) we created and also the queries and virtualizations we used to analyze our data. Finally, in part C, we are presenting the experiment we conducted by implementing the SGST to children with dyslexia and analysis of the results.

1.1 Serious Games

1.1.1. Defining Serious Games.

The rapid growths of Information and Communication Technology (ICT) transform learning and education over the last forty years. Many digital technologies changed the face of education and the way people learn. Serious Games is one of them most promising technologies. The term serious game is used to refer to a game designed for a primary purpose other than pure entertainment. The engaging and motivational aspects of serious games make learning more enjoyable that's why many sectors and organizations from business, health, military and education are considering the potential of serious games to support learning (Susi, Johannesson, & Backlund, 2007) .

The idea of using digital games for learning purposes is not new. Games used widely in military section during cold war. U.S. army invested a lot of money in research and many simulation games were created for training purposes (Djaouti, Alvarez, Jessel, & Rampnoux, 2011) .

The definition of serious games was first conceived by CC. Abt in 1970 and described as follows: “We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement” (Abt, 1970). Since then, many researchers attempt to propose a definition that it could be agreed on by all researchers. The variety of definition of serious games due to researchers approach different aspect and characteristics of them.

Some of them emphasize on the importance of gameplay. For example, Prensky’ s definition(Learning, 2001) for serious games is: “Entertainment games with non-Entertainment goal. Furthermore, Zyda’ definition (Zyda, 2005) “Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives”.

Moreover, Marsh (Marsh, 2011) defined and traced the history and state the characteristic of serious games. “Serious games are digital games, simulations, virtual environments and mixed reality/media that provide opportunities to engage in activities through responsive narrative/story, gameplay or

encounters to inform, influence, for well-being, and/or experience to convey”. Michael and Chen definition is probably the most identifiable “games that do not have entertainment, enjoyment, or fun as their primary purpose” (Michael D.R, 2005).

1.1.2. Classification and taxonomy of Serious Games

It is vital for researchers and scientist to define and categorize main characteristics of serious games. There are many proposal design frameworks and studies in literature which deal with that subject.

In (Djaouti, Alvarez, & Jessel, 2011) a model is proposed that classifies games according to “serious-related” and “game-related” characteristics. They focus their model on three criteria: a) gameplay, b) purpose of the game and c) market.

A well document classification and taxonomy is presented in (Laamarti et al., 2014). The authors suggest five criteria based on main characteristics of serious games:

- a) Activity: type of activity performed by the player.
- b) Modality: the way which information is passes through computer to player
- c) Interaction Style. Choosing interfaces such as keyboard, mouse or more modern interfaces such as movement tracking.
- d) Environment. Based on environment chosen for the game.

e) Application Area. Areas of implementation of serious games.

The proposed taxonomy is shown in the table above.

Application Area	Activity	Modality	Interaction Style	Environment
Education	Physical	Visual	Keyboard/ mouse	Social presence
Well-being	Psychological	Auditory	Movement Tracking	Mixed Reality
Training	Mental	Haptic	Tangible Interfaces	Virtual Environment
Advertisement		Smell	Brain Interfaces	2D/3D
Interpersonal Communication			Eye Gaze	Location Awareness
Health Care			Joystick	Mobility
Other		Others	Others	Online

Table1. Taxonomy of serious games

1.1.3. Effectiveness of Serious Games

There is a debate in scientific community about the effectiveness of serious games. Some researchers are convinced of effectiveness of serious game. Others argue that serious games could use only as a side teaching tool. Moreover, there are other opinions that serious games are oriented only on improving skills and provide better training. Clearly there is lack of experimentation and empirical evidence on effectiveness of serious games. In follow we present studies that focus on experimentation.

For example, Girard (Girard, Ecalle, & Magnan, 2013) reviewed the results of experimental studies designed to examine the effectiveness of Video Games and Serious Games on players learning and engagement. In this meta-analysis,

the author's teams identify all the experimental studies that have used Serious Games for training or learning and assessed their results in terms of both effectiveness and acceptability. They concluded that the effectiveness of serious games remains to be proven. Only a few of the games resulted in improved learning, with the others having no positive effect on knowledge and skills when compared with more traditional methods of teaching.

Additionally, Anetta (Anetta, Minogue, Holmes, & Cheng, 2009) experimental study evaluated a teacher created video game on genetics in terms of its affective and cognitive impact on student users. The study was set in four general biology classes from a single high school in the South Eastern United States. All four classes were taught by the same teacher. The statistical results of this study indicated that despite being more engaged in the instruction students who played serious game did not demonstrate a greater understanding of the genetics concepts presented.

Furthermore, Sitzmann (Sitzmann, 2011) published a meta-analysis of 55 research reports relating to the instructional effectiveness of simulation games. The author used the term 'simulation game' in order to describe the type of the games. The author outlined the importance of certain positive factors for improving learning during training using simulation games. Concluded that technology can improve learning but added that '*technology is a means for delivering teaching but does not have a direct effect on learning*'.

In addition, in (Backlund & Hendrix, 2013) present a meta-analysis of effectiveness on serious games based on studies which used empirical evidence. They review research that took place in the last decade. The analysis concentrates on usage in formalized school content. They survey forty studies, which twenty-nine of them show positive results in effectiveness of serious games.

Finally, a well-documented meta-analysis on serious games and games published by Connolly (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). The study identified 129 papers reporting empirical evidence about the impacts and outcomes of computer games and serious games with respect to learning and engagement. While empirical evidence concerning the effectiveness of games-based learning was found in this review, the need for more research to provide more rigorous evidence of their effectiveness is vital.

1.1.4. Success Factors in SG Design and Development

There many factors that make a SG successful. In the following, we present some success factors and suggested frameworks drawn from the literature.

In (Kiili, De Freitas, Arnab, & Lainema, 2012) authors describe a flow framework in order to build interest and successive serious games. This model is based on upon associative, cognitive and simulative learning theories.

Furthermore, in (Arnab et al., n.d.) presented a design framework oriented in pedagogical aspects of serious games. The authors suggest that next generation serious games should focus more on encapsulating learning theories and learning goals mapping to game mechanics.

Finally, in (Laamarti, 2014) authors indicate some critical factors that will be important in accelerating serious games towards mass adoption. These are briefly the followings:

- a) User-centered software engineering
- b) Multimodal serious games
- c) Social well-being
- d) Adaptive gaming
- e) Standardization of evaluation
- f) Sensory-based simulations

1.1.5. Platforms

In (Connolly et al., 2012) authors present the most popular platforms for distribute games. Most popular platform for delivering serious games is Personal Computers. Followed from online games. Here we presently briefly in Table 2 the outcomes of research started from the most popular:

Delivery Platforms
PC
Online games
Mobile
Video console

Virtual world (Second Life)

Table 2. Popular Delivery platforms

1.1.6. Favorite topics and subjects

As shown in (Backlund & Hendrix, 2013) lead in favorite topics of serious games in formal education, primary, secondary and higher education is mathematics. It seems that there are there positive results in learning emphatics by using serious games.

Another favorite subject is teaching second language through serious game. It seems that features of a game serve well the learning of languages.

We present a brief list in [Table 3](#) with most popular topics as presented in this study (start from more popular)

Popular subjects
Mathematics
Second Language
Computer science
Geography
History
Natural sciences
Surgery (higher education)

Table 3. Popular topics in serious games

1.1.7 Serious Games Analytics (SGA)

1.1.7.1. Big Educational Data-Learning Analytics

Large amounts of educational data are captured and generated on a daily basis from different sources and in different formats for education systems all over the world.

There are different kinds of educational data that produced constantly, such as student's interaction with Learning Management Systems (LMS), learning activities, examination results. In addition, other kind of data related to administrative, educational and quality improvement processes and procedures (Vaitsis, Hervatis, & Zary, 2016).

There are two challenges that derived from big educational data (Ferguson, 2012). The first is the technology challenge: how can we retrieve and extract value from educational data which are distributed across a variety of different sites with different standards, owners and levels of access. The second challenge is how we optimize opportunities for online learning.

Data-driven approaches that rely on gathering and analyzing data are a current trend in the e-learning community. Disciplines such as Educational Data Mining (EDM) and Learning Analytics (LA) are studying the way learners perform online activities.

Data mining (DM) is a computer-based information system (CBIS) devoted to scan huge data repositories, generate information, and discover knowledge (Peña-Ayala, 2014).

Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs.

1.1.7.2. Serious Games Analytics

Serious game can produce massive user data. The interactive nature of serious games makes them a good source of LA data. It can pose an advantage to feed LA systems, providing a learning dashboard for all the stake holders involved in learning process.

In (Loh, 2015) serious games analytics are defined as the “actionable metrics developed through problem definition in training/learning scenarios and the application of statistical models, metrics, and analysis for skills and human performance improvement and assessment, using serious games as the primary tools for training.”

Serious games analytics can be derived from tracing players’ game play and the visualization of their actions, behaviors within gaming environments. In (Serrano-Laguna et al., 2017) review how learner’s interaction are tracked in serious games and present an interaction model which encompass five main categories , we summarized them as following:

- a) Completables: indicates the player’s level of progress in a SG

- b) Alternatives: deals with each of the in-game decisions a player performs during a gameplay.
- c) Meaningful variables: deals with each of the values that represent something.
- d) Custom interactions: There are serious games and educational scenarios that will benefit from tracking very specific player interactions with great detail, for example, to facilitate a manual subjective analysis of the interaction.

As we have defined the targets and actions presented in serious games we need a real notation to represent them. We can take advantage of standardization efforts currently underway in the field of LA in order to represent serious games analytics.

1.2. Experience Application Programming Interface- xAPI

1.2.1. A brief history in learning specifications

It was only in 1960 when the first Computer Based Training (CBT) program was introduced to the world. This computer based training program was known as PLATO-Programmed Logic for Automated Teaching Operation (Pascal, 2011). It was originally designed for students attending the University of Illinois but ended up being used in schools throughout the area. Since then, and with the

introduction of the personal computers and internet, eLearning tools and delivery methods expanded.

Initially, many courses delivered via CD-ROMs and laser disks. These led to the Learning Management systems (LMSs). An LMS is a software application for the administration, documentation, tracking, reporting and delivery of educational courses or training programs. In 1989 AICC released the first specification for the LMSs (AICC Document Arc, 2014). This specification allowed students' scores to be tracked on the computer system he was using. In 1993, the AICC created the CMI specification—still in use today—which specified the communications between a course and an LMS. The specification was originally intended for CD-ROM or local file-based content.

During the transition from computer-based training (CBT) on compact discs (CDs) to eLearning on the web one of the major challenges with the content delivery was interoperability of the content. Several eLearning standards were founded in late 90s such as the IMS Global Learning Consortium (IMS, 2018), (AICC CMI Subcommittee & Bergstrom, 1993), and the Advanced Distributed Learning (ADL) Project.

In 2001 SCORM (Shareable Content Object Reference Model) was released by the ADL Project. SCORM is the de facto specification for packaging learning content is a standard format which allows the package to work in different LMSs (Advanced Distributed Learning, 2018). The SCORM® has several version releases dating back to the year 2000 starting with SCORM® 1.0. SCORM® 1.2,

released in 2001 is the first version of SCORM® that was widely adopted. Beginning in 2004, SCORM® began to release different editions of SCORM® 2004 based on iterative fixes and improvements. The most recent release (2009) is SCORM® 2004 4th Edition.

1.2.2. What led to the development of XAPI

Since SCORM first released in 2000 the landscape has changed rapidly. SCORM has served well of achieving interoperability in different LMSs, but it really doesn't capture the entire picture of e-learning in nowadays. SCORM is constrained to tracking specific course-oriented things like lesson pages viewed, test scores, and module completions. SCORM also relies on JavaScript, which makes it difficult to implement in mobile apps.

Learning is happening everywhere, not just in traditional SCORM courses inside traditional LMSs. Learning is occurred in a series of experience. People are using mobile devices such as smartphones and tablets to receive information, communicating, learning and collaborating amongst themselves. Moreover, the expand of social media influence the way people learn.

Around 2010, ADL recognized a need to define an updated standard that could overcome many of SCORM's inherent limitations. The need of capturing all the learning experiences lead ADL of the US Department of Defense and Rustici, an eLearning software company, to work on a new proposal for the

new generation of eLearning specification (Lim, 2015). In April 2013, Rustici released the Tin Can API, which later renamed it xAPI, for Experience API. The current version is at version 1.0.3 released in 2017 (adlnet, n.d.).

1.2.3. What is the experience API Specification

The Experience API (or xAPI) is a new specification for learning technology that makes it possible to collect data about the wide range of experiences a person has (online and offline). With the xAPI, e-learners can take e-learning outside of the browser. This API captures data in a consistent format about a person or group's activities from many technologies (Corbi & Burgos, 2014). Very different systems are able to securely communicate each other by capturing and sharing this stream of activities using xAPI's simple vocabulary.

In addition, xAPI defines independent mechanisms, protocols, specifications, agreements and software tools for monitoring any imaginable scenario. Moreover, xAPI allows e-learning to execute in native mobile applications simulations, wearables, physical beacons, and more. Some of the micro-behaviors, state, and context that xAPI can track we summarize them as followed (adlnet, 2017):

- a) Reading an article or interacting with an eBook
- b) Watching a training video, stopping and starting it
- c) Training data from a simulation
- d) Performance in a mobile app

- e) Micro-interactions with e-learning content
- f) Team performance in a multi-player serious game
- g) Quiz scores and answer history by question

Finally, the Experience API is an open-source and free initiative, whose source code and specifications are open to anyone.

1.2.4. xAPI Statements

The most significant object within the xAPI data model is the "Statement" object. It is a Representational state transfer (REST) web service. xAPI uses JavaScript Object Notation (JSON) to transfer states/sentences to a central web service. This web service allows clients to read and write data in the form of sentence objects that share the foundations of the triple scheme. In their simplest conception, sentences are in the form of actor, verb and object/activity like the example in [Fig 1](#).

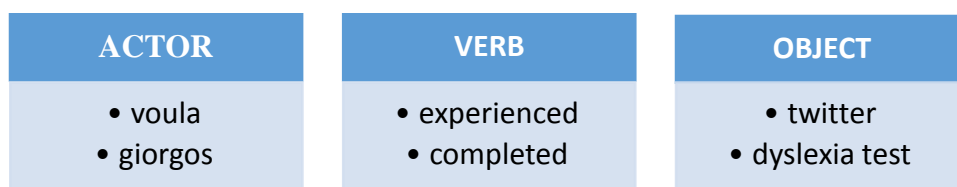


Fig 1. The basic elements and Structure of xAPI

The statement object itself would take this structure in JSON (JavaScript Object Notation) format and could resemble the following:

```
actor": {
  "objectType": "Agent",
  "mbox": "mailto:Mar8@mar.gr",
  "name": "261208" },
"verb": {
  "display": {
    "en-US": "passed"
  }, },
"object": {
  "definition": {
    "type": "http://adlnet.gov/expapi/activities/course",
    "name": {
      "und": "DYSLEXIA SCREENING TOOL"
    }
  }
}
```

More complex statement forms can be used. The set of verbs and objects an institution can work with is called *vocabulary*. Each institution can define its own vocabulary with no restriction.

1.2.5 xAPI statements and Serious Games

In the previous section, we have defined the targets and actions that need to be track and analyze in serious games. xAPI is an appropriate standard to represent serious games analytics. In (Serrano-Laguna et al., 2017) [authors](#) present an interesting mapping between interactions events in SG to xAPI statements attributes . They also proposed a mapping between target type in SG and xAPI activities. We present them in [Table 4](#) and [Table 5](#)

Interaction Event SG	xAPI statement attributes
----------------------	---------------------------

UserId - NAME	Actor
Action	Verb
Target	Object
Value	Result
Timestamp	Timestamp

Table4. Mapping of interactions in SG to xAPI statements

Action	Verb	Definition
Start	http://adlnet.gov/expapi/verbs/initialized	Indicates the activity provider has determined that the actor successfully started an activity.
Progress	http://adlnet.gov/expapi/verbs/progressed	Indicates a value of how much an actor has advanced or moved through an activity.
Complete	http://adlnet.gov/expapi/verbs/completed	Indicates the actor finished or concluded the activity successfully.
Select	https://w3id.org/xapi/adb/verbs/selected	Indicates the selected choices, favored options or settings of an actor in relation to an object or activity.

Table5. Mapping of event action in SG to xAPI verbs

1.2.6. Learning Records Stores (LRS)

An LRS enables modern tracking of a wide variety of learning experiences, including real world activities, mobile apps and even job performance. Data from these experiences can be shared with other systems for reporting analytics and to support adaptive learning experiences. As the LRS collects data from a range of experiences, these sets of data can be compared and collated to evaluate the effectiveness of training programs and learning solutions (Software Rustici, n.d.).

A Learning Record Store (LRS) is the implementation of the server-side requirements associated with the xAPI specification. The LRS is a key component of the xAPI architecture. As xAPI-enabled activities generate statements, they are sent to an LRS (Lim, 2016) as shown in Fig2. It is the application interface for storing, accessing, and often visualizing the data about learning experiences, activities, and performance.

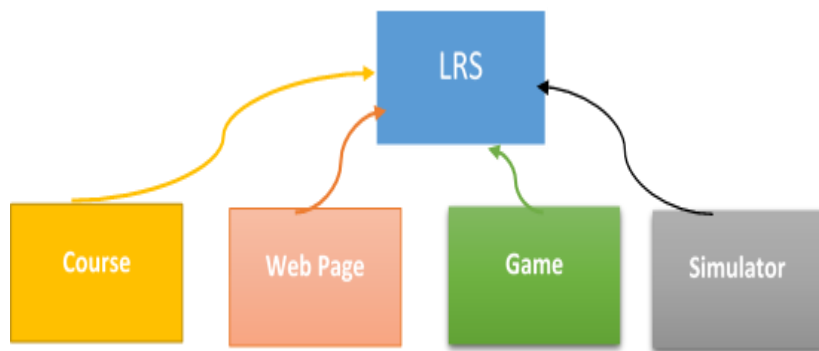


Fig2. Learning Record Store

An LRS is nothing more and nothing less than a wrapper or API software layer to an SQL database (initially, a PostgreSQL instance in the original Rustici implementation). This LRS implementation was open-sourced by ADL (available at its Github repository) and is based on the Python computer language and on the publicly acclaimed Django web framework (Corbi & Burgos, 2014).

Learning Record Store

OAuth	Basically	HTTP
-------	-----------	------

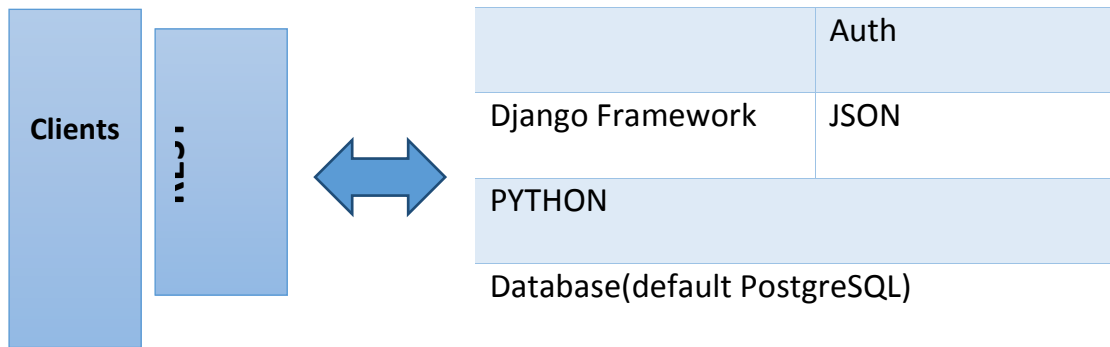


Fig3. Usual LRS software stack and interaction

As shown in Fig 3, an LRS must also implement REST calls for data transfer (PUT, POST, GET and DELETE). The Experience API can make use of either OAuth or HTTP Basic Authentication when communicating with the outside world, ensuring a certified and secured dialogue between clients (usually an LMS) and the LRS service.

Moreover, a key factor of LRSs is that can connect to each other and share data amongst themselves. Data can be transfer from one organization to another, from one ecosystem to another. In other words, monitoring data can be uniformly stored, allowing rapid, vast and democratic access to learning analytics information.

There are several different ways that statements can be moved between LRS

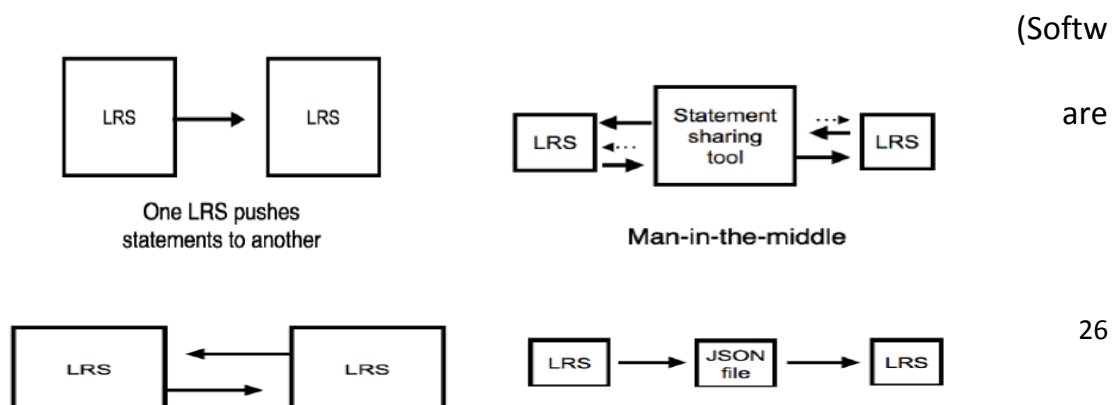


Fig4. Share Statements between LRSs

Rustici, n.d.):

- a) One approach is to have one LRS share its statements with another. This means that all statements in one LRS are transferred to another, but any statements already in the second LRS are not transferred back to the first.
- b) Two ways sharing: An extension of one-way sharing is to additionally share statements in the other direction such that all statements in each LRS are shared with the other Both LRSs sending on their statements to the other.
- c) Man-in-the-middle application. It's also possible to share statements using a 3rd party, man in the middle application that sits outside the LRSs.
- d) Download and upload.

Finally, statements can be between LRSs by downloading the statements as a JSON document from one LRS and uploading it to another.

1.2.7. The growth of xAPI

The Experience API was released, as version 1.0, in April 2013, and there are, as of today, over 100 adopters, projects and companies involved. A list of

companies who's adopting to xAPI such as those("Who's using the Experience API?," n.d.).



Fig5. Adopters to xAPI

1.3 Authoring Tools

The eLearning market globally continues to evolve. The rapid growth of eLearning leads to expanded need of content creation. According to Research and Markets Report (Docebo, 2016), the global content authoring tools market is expected to grow at a CAGR of 7.72% over the 2017-2021 period.

Authoring tools are software applications used to develop eLearning products. They generally encompass capabilities to create and manage eLearning activities. In simple terms, an authoring tool is an eLearning course creation tool that allows anyone, not just programmers, to create, package and deliver engaging contents of eLearning (Khademi, Haghshenas, & Kabir, 2011).

Moreover, authoring tools generally use WYSIWYG (“what you see is what you get”) interfaces allowing users to easily manage eLearning assets. They reduce the skill set requirements for the development process and decrease technical overhead.

Authoring tools range from simple tools that convert slides to web pages to advanced software for creating complicated applications.

1.3.1. Categories of authoring tools

There are nine major categories of authoring tools according to ADL (Berking, 2018).

- Learning content management systems: These applications combine the authoring functions with content management and delivery
- Self-contained authoring environments: These applications create entire eLearning courses using capabilities within the authoring tool.
- Virtual classroom systems: These are platforms specifically for creating content that is delivered via an online collaboration tool.
- Mobile learning development tools: These authoring tools are using mobile screen templates and provide output files that work with mobile device operating systems.
- Social Learning development tools: Create learning that is based on learner-generated content (eg wikis, video sharing, social networking, blogs).

- Performance support development tools: These are tools to specifically author performance support modules.
- External document converter/optimizer tool: These tools provide limited ability to develop eLearning content from scratch. They are designed to import external documents and convert them to web-based eLearning formats (HTML5 or Flash) by adding some interactivity.
- Intelligent Tutoring Systems (ITS): This technology, dynamically generates instruction in real time through artificial intelligence algorithms and also mimics the behavior of an expert human tutor.
- Auxiliary tools: These tools accumulate objects created in other tools into an organization/sequence of learning objects, usually to produce SCORM packages.

In [Fig6](#) is presented the main categories and subcategories of the existing authoring tools. The categories are not mutually exclusive. Many authoring tools have attributes that qualify them for two or more categories.

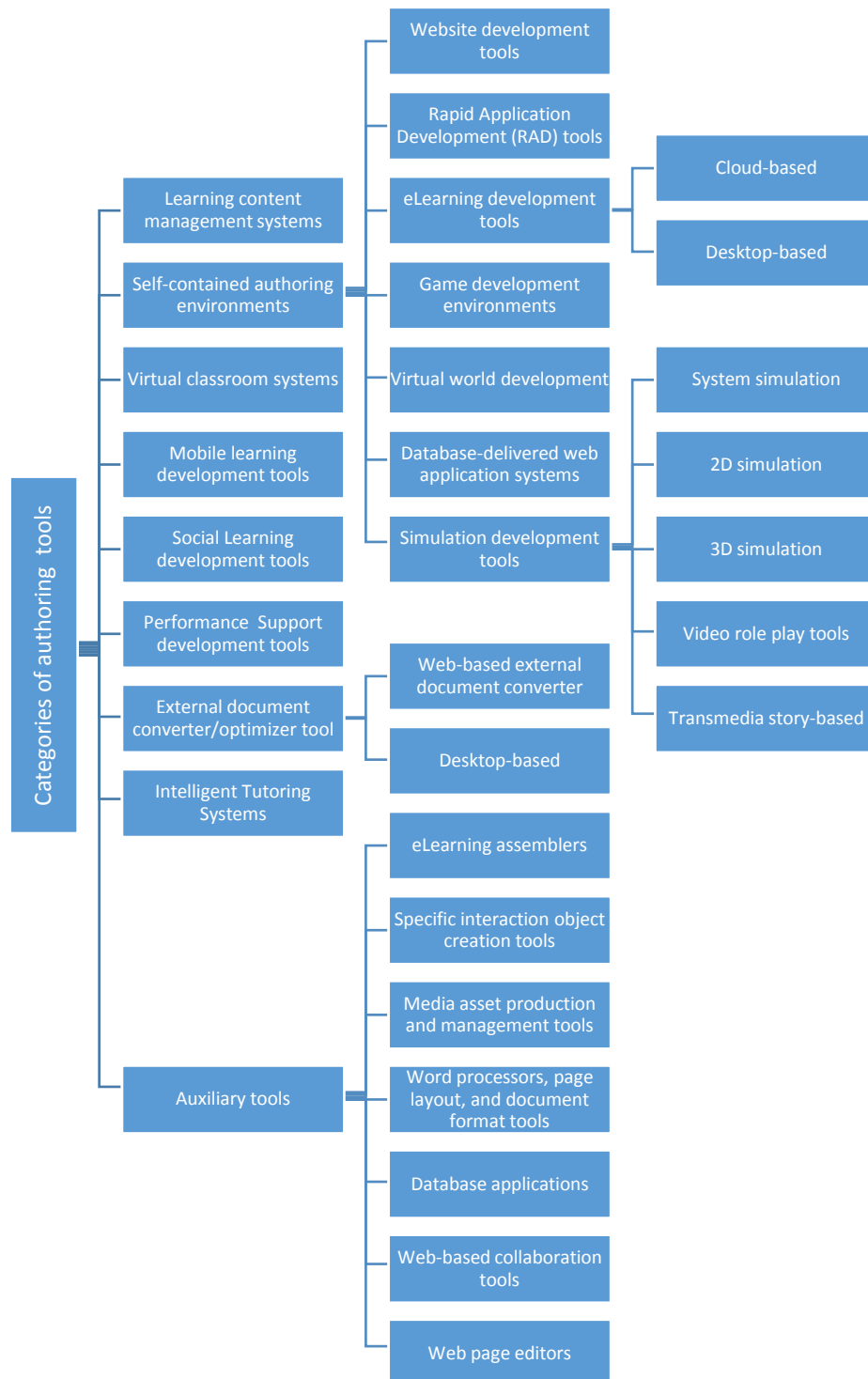


Fig6. ADL's authoring tool classification

1.3.2 xAPI and authoring tools

Adoption to xAPI is almost ubiquitous amongst authoring tool vendors (ADL, 2018). The majority of authoring tools support xAPI specification albeit to

varying degrees. Some authoring tools simply use built-in xAPI statements to replicate SCORM's tracking mechanisms, but other tools have a bit more capability.

Moreover, the vast majority of authoring tools such as Articulate Storyline (Articulate, n.d.) , iSpring ("iSpring," n.d.) and Captivate(Captivate, n.d.) will allow you to send xAPI statements, but with low levels of customization. By default, you'll get pre-described verbs – a preset (e.g. "completed", "experienced", "passed" as a response to quiz questions). This approach does not tap into the full power of xAPI. However, authoring tools such as Lectora (Lectora, n.d.) and Claro (Claro, n.d.) are further ahead, and allow you to generate an xAPI statement for anything on a page as well as selecting the verb used for that statement. Finally, with the exception of Storyline all authoring tools at present can only send and not retrieve xAPI statements (Putman, 2016).

In (Foreman Steve, Wiggins Craig, Berkins Peter, 2015) authors suggest how authoring tools can provide more robust support for xAPI in the future. We summarize their viewpoints as following:

- a) bi-directional communication between the content and the LRS,
- b) focus on performance-based assessment,
- c) adaptive contented, and
- d) focuses on tools made for a specific context or use case.

1.4. Dyslexia

1.4.1. Dyslexia

“Dyslexia is a neurodevelopmental disorder characterized by deficits in the ability to learn or to use specific academic skills. Dyslexia is a cross-cultural and chronic condition that typically persists into adulthood” (APA, 2013).

Prevalence of dyslexia is controversial, ranging worldwide from 5-15% (Vlachos et al., 2013), (Peterson & Pennington, 2015) with a significant male predominance with sex ratios ranging from 1.5:1 to 3.1:1. These great discrepancies are due to methodological differences among studies and mainly due to the use of many terms in the past to describe dyslexia (López-Escribano, Sánchez, sciences, & 2018, 2018),(Rutter et al., 2004), (Hawke, Olson, Willcut, Wadsworth, & DeFries, 2009), (Vlachos et al., 2013) .

Dyslexia is characterized by specific impairment of reading and spelling which cannot be explained by delayed development of cognitive abilities or low intelligence.

Early signs of learning difficulties may appear in the preschool years (e.g., difficulty learning names of letters or counting objects), but they can only be diagnosed reliably after starting formal education (APA, 2013).

1.4.2. DSM-V: Diagnostic criteria of dyslexia

Diagnostic and Statistical Manual of Mental Disorders DSM-V: Diagnostic criteria of dyslexia (APA, 2013):

A. “Difficulties learning and using academic skills, as indicated by the presence of at least one of the following symptoms that have persisted for at least 6 months, despite the provision of interventions that target those difficulties:

1. Inaccurate or slow and effort-full word reading (e.g., reads single words aloud incorrectly or slowly and hesitantly, frequently guesses words, has difficulty sounding out words).
2. Difficulty understanding the meaning of what is read (e.g., may read text accurately but not understand the sequence, relationships, inferences, or deeper meanings of what is read).
3. Difficulties with spelling (e.g., may add, omit, or substitute vowels or consonants).
4. Difficulties with written expression (e.g., makes multiple grammatical or punctuation errors within sentences; employs poor paragraph organization; written expression of ideas lacks clarity).
5. Difficulties mastering number sense, number facts, or calculation (e.g., has poor understanding of numbers, their magnitude, and relationships; counts on fingers to add single-digit numbers instead of recalling the math fact as peers do; gets lost in the midst of arithmetic computation and may switch procedures).

6. Difficulties with mathematical reasoning (e.g., has severe difficulty applying math concepts, facts, or procedures to solve quantitative problems).
- B. The affected academic skills are substantially and quantifiably below those expected for the individual's chronological age, and cause significant interference with academic or occupational performance, or with activities of daily living, as confirmed by individually administered standardized achievement measures and comprehensive clinical assessment.
- C. The learning difficulties begin during school-age years but may not become fully manifest until the demands for those affected academic skills exceed the individual's limited capacities (e.g., as in timed tests, reading or writing lengthy complex reports for a tight deadline, excessively heavy academic loads).
- D. The learning difficulties are not better accounted for by intellectual disabilities, uncorrected visual or auditory acuity, other mental or neurological disorders, psychosocial adversity, lack of proficiency in the language of academic instruction, or inadequate educational instruction."

Specifiers for Dyslexia

Specification of all academic domains and subskills that are impaired at the time of assessment, from the following (APA 2013):

1. “With impairment in reading: Word reading accuracy, reading rate or fluency and reading comprehension.
2. With impairment in written expression: Spelling accuracy, Grammar and punctuation accuracy, Clarity or organization of written expression.
3. With impairment in mathematics: Number sense, memorization of arithmetic facts, accurate or fluent calculation, accurate math reasoning.”

1.4.3. Severity rating for Dyslexia

The severity rating for Dyslexia classified as following

- **Mild**
- **Moderate**
- **Severe**

Severity is based on the range of academic skills affected and on the anticipated ability to compensate or need for accommodations or other supportive services (APA, 2013).

1.4.4. Etiology

Despite decades of intensive research, the underlying biological and cognitive causes of dyslexia remain currently unknown. Dyslexia has not a single underlying cause. The etiology of Dyslexia is complex and includes the interaction of genetic, epigenetic, and environmental factors in its etiology (Hendren, Haft, Black, White, & Hoeft, 2018), (GORKER et al., 2017). The estimated heritability rate of dyslexia is approximately 50–70% (Hawke et al., 2009), (Peterson & Pennington, 2015). The relative risk of dyslexia is 4-8 times higher in first-degree relatives of individuals with these learning difficulties compared with those without dyslexia.

1.4.5. Comorbidity of Dyslexia

Dyslexia is highly comorbid with other developmental and psychiatric disorders. The most prevalent comorbid disorders are Specific Language Impairment, Attention Deficit Hyperactivity disorder, Autistic Spectrum Disorders, Anxiety and Depressive Disorders (Hendren et al., 2018), (Ramus, Marshall, Rosen, & Van Der Lely, 2013), (Talli, Sprenger-Charolles, & Stavrakaki, 2016), (Sciberras et al., 2014), (Mayes & Calhoun, 2006), (Scerri et al., 2011),

1.4.6. Diagnosis of Dyslexia

There is no single test or a blood test that can diagnose dyslexia. Diagnosis of Dyslexia is made on clinical grounds, based on the developmental clinical picture of the child and his academic, social and medical history. Differential diagnosis is also challenging as dyslexia is highly comorbid disorder. Rating scales are valuable in screening for deficits, but they cannot substitute the clinical diagnosis.

1.4.7. Dyslexia in Greece

Despite dyslexia is official recognized by Greek educational law, there is no official screening and diagnostic protocol for diagnostic centers. Furthermore, there is no school based screening protocol for dyslexia. Evaluation and referral of children is based on empirical and subjective assessments of their teachers. There are also few professionals adequately trained for diagnosing dyslexia. Screening tools are few and not efficient standardized and therefore rarely used in clinical practice.

In conclusion, diagnosis of dyslexia is based primarily on personal experience, relying on the overall impression than on specific measurement (Protopapas, 2008), (Protopapas & Skaloumbakas, 2007).

1.4.8 Related Work

The literature on using ICT to assess dyslexia is limited, inadequate and rather dated.

The most widely used ICT screening test for dyslexia is Cognitive Profiling System (CoPS) (Singleton, Thomas, & Horne, 2000) developed in United Kingdom. CoPS is comprised of 8 subtests assessing working memory, auditory and color discrimination and phonological awareness in 4 to 8-year-old children. The test has many versions and is adapted in other languages Italian, Swedish, and Norwegian (Singleton et al., 2000) (Brookes, Ng, Lim, Tan, & Lukito, 2011).

In addition, there are many tests, such as Dyslexia Screener (“Dyslexia Screener,” n.d.), Cognitive Aptitude Assessment software (“Cognitive Aptitude Assessment,” n.d.), Comprehensive Diagnostic Assessment of Reading Difficulties (“Comprehensive Diagnostic Assessment,” n.d.), which are designed to assess learning disorders. These tests are not published in peer reviewed journals and thus their validity is restricted and debatable.

In Greece the literature on ICT assessment for dyslexia is insufficient. There are two ICT screening tests, VLEMA and Lamda (Christos, Skaloumpakas, 2007). VLEMMA is designed to assess dyslexia in children attending 3rd and 4th grades. Lamda in first released version was designed to assess dyslexia for 2nd grade to 4th grade students and in second version for 5th to 8th grade

students. The validity and reliability of both tests is restricted due to their many methodological limitations.

Undoubtedly, ICT screening tools, developmentally adapted and validated is feasible, can be used massive in schools, covering the above mentioned existing lack of a ICT assessment. For Greek educational system, where many schools are isolated and the access to diagnostic centers is complicated and time-consuming, the use of ICT screenings tools would be beneficial.

Despite the many advantages of ICT screenings tool, interpretation of their results must be made with caution and in the light that they identify in the population children at risk for dyslexia, who need further assessment (Brookes et al., 2011), (Protopapas, 2008), (Singleton, 2001), (Protopapas & Skaloumbakas, 2007).

2. PARTB. Implementation Phase.

In this part, we are describing the following:

- a) the analysis, design and implantation of SGST.
- b) the installation, the structure and the design of the Learning Locker LRS.

2.1 Analysis- Design- Implementation of SGST

2.1.1. Theoretical Framework of SGST's.

2.1.1.1. Analysis of Reading and Spelling in Greek language

All alphabetic writing systems use graphemes to represent phonemes. Learning to read and write an alphabetic system depends on children's' ability to analyze and segment words into phonemes and connect these to the corresponding graphemes. This cognitive procedure is defined as phonological awareness (Aidinis & Nunes, 2001), (Stein, 2018).

Greek language has a relatively low orthographic complexity characterized by an almost 1:1 mapping from graphemes to phonemes (Porpodas, 1999). Learning to read is easier in consistent orthographies than in deep orthographies. However, phonologically, it's not opaque for spelling as there is a 1: many- phonemes-graphemes mapping (Niolaki, Terzopoulos, & Masterson, 2014), (Porpodas, 1999) .

Therefore is easier to read based on direct decoding, but it's impossible to spell correctly based on the words pronunciation alone (Protopapas, Fakou,

Drakopoulou, Skaloumbakas, & Mouzaki, 2013), (Protopapas & Skaloumbakas, 2007), (Protopapas, 2008).

Spelling and reading performance is depending on phonological awareness of a language (Protopapas et al., 2013), (Aidinis & Nunes, 2001). The phonological deficit hypothesis remains the most dominant among other regarding the etiology of dyslexia (Talli et al., 2016),(Ramus et al., 2013), (Caravolas & Volín, 2001) (Manolitsis & Georgiou, 2015).

Children with dyslexia are characterized by deficits in phonological reading skills (decoding skills), phonemic awareness, phonological short-term memory and impairment in reading comprehension (Waldie, Wilson, Roberts, & Moreau, 2017), (Talli et al., 2016)(Τάφα Ε, 2009).

It's also well documented that dyslexia in transparent orthographies is more strongly associated with slow than inaccurate reading, caused by phonological impairment (Sotiropoulos & Hanley, 2017),(Porpodas, 1999). Thus, a crucial factor when assessing for dyslexia is the time children need to read words. Moreover, their reading often remains slow and effortful with persistent spelling and written expression deficits (Habib, 2000) .

Furthermore, spelling errors in dyslexia can be classified into orthographic and phonological (Protopapas et al., 2013). Greek children in 1st and 2nd grade spell words mainly based on phoneme-grapheme correspondences and not on orthographic lexical representations(Georgiou, Manolitsis, Zhang, Parrila, & Nurmi, 2013). In general it seems that phonological development influence

spelling functioning in dyslexia (Porpodas, 1999),(Protopapas et al., 2013),(Aidinis & Nunes, 2001).

Additionally, reading comprehension in dyslexia is associated with word accuracy, fluency and spelling skills of the children (Learning to Read Greek, 2017). Reading comprehension is relatively poor in 2nd grade children despite successful identification of individual text's words (Aidinis, 2012)(Georgiou et al., 2013). Second grade children with dyslexia could be identified on the basis of poor word reading skills performed in comprehension tasks (Constantinidou & Stainthorp, 2009).

2.1.1.2. Design of the SGST

The present SGST is designed to identify children at risk for dyslexia at the end of 2nd grade and at the beginning of 3rd grade of primary school. The SG can be also implemented in children of the 3rd grade with severe specific learning disorder.

We collaborate with Special Educators and Scientific Associates of Child and Adolescent Mental Health Clinic of Venizeleio General Hospital of Heraklion to help us design this diagnostic tool.

The SGST - test is based on DSM-V (APA 2013) diagnostic criteria for dyslexia and its developmental adapted to screen phonological, spelling and comprehension deficits in Greek language.

It is comprised of two major domains, the phonological awareness and reading comprehension (as we described them in the previous section) and a smaller but not diagnostic one, the left and right conception domain. Each domain is sub-divided into smaller tasks-subtests.

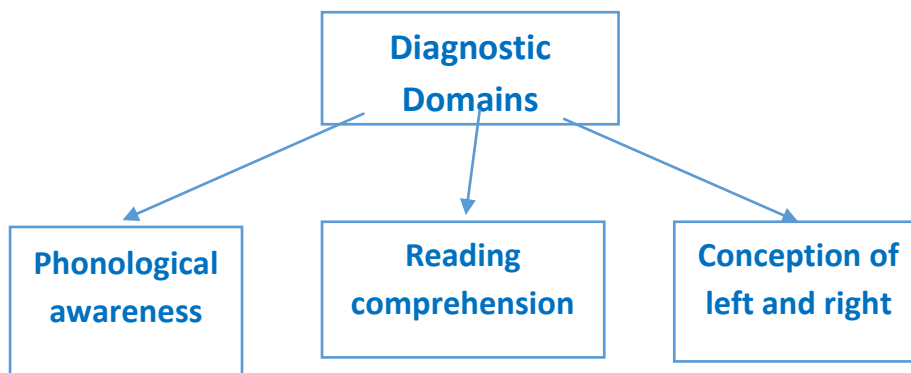


Fig7. Assessment Domains of the SG

The phonological awareness domain is comprised of 4 subtests: the spelling subtest, the syllabic segmentation subtest, the optical discrimination of correct spelling words subtest and the syllabic word composition subtest. Each task is composed with a set of questions- activities. These subtests measure the child phonological awareness in spelling and composing words.

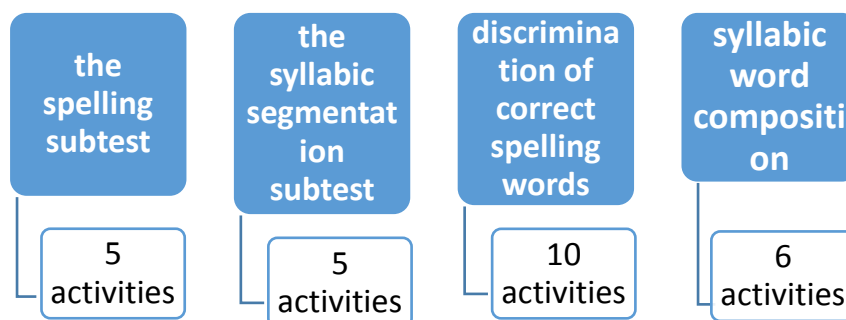


Fig8. Phonological awareness subtests

The reading comprehension domain is comprised of 3 subtests: The small sentence comprehension subtest, the metagnostic reading comprehension

subtest and the word supplementation in text subtest. These subtests measure the child reading comprehension skills which include the ability to understand as well as to draw conclusion and make inferences of text read.

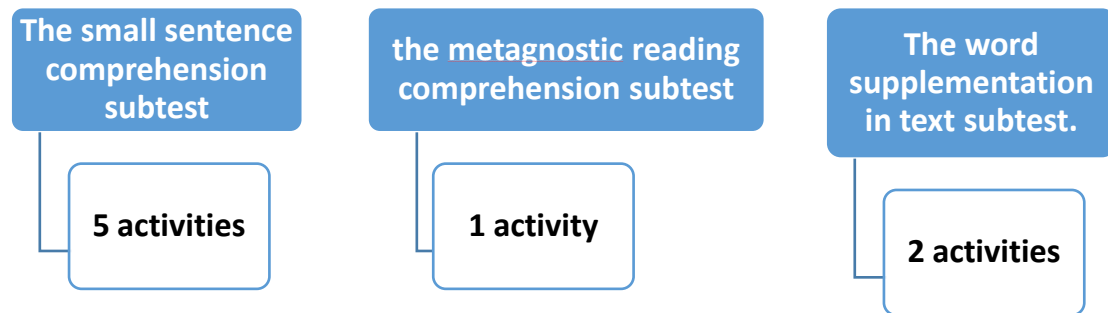


Fig9. Reading comprehension domain

The left-right recognition domain has no predictive value in the test, although results can be included in the clinical picture of the child, as deficits in this domain often co-occur with dyslexia (Shovman & Ahissar, 2006). This subtest contains 3 activities.

Moreover, all the subtests are coming with time frames, as the time of processing of the child in each domain is a crucial parameter in assessing dyslexia. Time frame was set after the pilot implementation of the SGST to 8 children with no learning disabilities and to 5 children with a diagnosis of dyslexia. We set the time frame for each activity using the average response time that children with dyslexia and children without dyslexia needed to complete the activity.

In addition, each activity was scored according to the level of difficulty. We classified the activities into three levels of difficulty, low medium and high and we scored them as it's depicted in [Table6](#).

	subtest	ACTIVITIES	LEVEL OF DIFFICULTY	POINTS	TIME	
Phonological awareness	spelling	ACTIVITY 1	medium	1	1 min	
		ACTIVITY 2	medium	1	1 min	
		ACTIVITY 3	medium	1	1 min	
		ACTIVITY 4	medium	1	1 min	
		ACTIVITY 5	medium	1	1 min	
	syllabic segmentation	ACTIVITY 6	medium	1	1 min	
		ACTIVITY 7	medium	1	1 min	
		ACTIVITY 8	medium	1	1 min	
		ACTIVITY 9	medium	1	1 min	
		ACTIVITY 10	medium	1	1 min	
	optical discrimination of correct spelling words	ACTIVITY 11	easy	0,5	30 sec	
		ACTIVITY 12	easy	0,5	25 sec	
		ACTIVITY 13	easy	0,5	30sec	
		ACTIVITY 14	easy	0,5	25sec	
		ACTIVITY 15	easy	0,5	30sec	
		ACTIVITY 16	easy	0,5	30sec	
		ACTIVITY 17	easy	0,5	30sec	
		ACTIVITY 24	difficult	3	2min	
		ACTIVITY 25	difficult	3	1m30sec	
	ACTIVITY 26	difficult	3	2min		
	syllabic word composition	ACTIVITY 18	easy	0,5	50sec	
		ACTIVITY 19	easy	0,5	30sec	
		ACTIVITY 20	easy	0,5	40sec	
ACTIVITY 21		medium	1	50sec		
ACTIVITY 22		medium	1	50sec		
ACTIVITY 23		medium	1	50sec		
Reading comprehension		small sentence comprehension	ACTIVITY 27	easy	2	2,5min
	ACTIVITY 28		easy	2	2,5min	
	ACTIVITY 29		easy	2	2,5min	
	ACTIVITY 30		easy	1,2	2min	
	ACTIVITY 31		easy	1,2	2 min	
	metagnostic reading comprehension	ACTIVITY 35	difficult	8	5min	
	word supplementation in text	ACTIVITY 36	difficult	4	4min	
		ACTIVITY 37	difficult	5	5min	
	conception of left and right	conception of left and right	ACTIVITY 32	medium	0	1,5min
			ACTIVITY 33	medium	0	1,5min
ACTIVITY 34			medium	0	1,5min	

**activity numbers follows the order of SGST's report (cited in Apprentice 2.*

Table6. Activities Score and Time

Moreover, the feedback to user in each activity is always positive regardless of the outcome. Positive feedback is an important element in children’s motivational behavior and more important to dyslexic children who are used in failing into assignments.

2.1.1.3. Scoring the SGST

Each diagnostic domain is scored and evaluated independently. In [Table 7](#), we summarize the total score points of each major domain.

Diagnostic Domain	ACTIVITIES	Points
A. Phonological Awareness	26	27
B. Reading Comprehension	8	26
C. Conception of left and Right	3	0
Total	37	53

Table7. Diagnostic Domains Score

In phonological awareness domain, the scores of 4 subtests are combined (by adding points from successful activities) to derive an overall probability of dyslexia and classifies children into 3 categories: highly probable- clinical range with score <60%, Borderline probable with score <60-70% and Normal with score >70%.

In reading comprehension domain, the scores of 3 subtests are combined (by adding points from successful activities) to derive an overall probability of dyslexia and classifies children into 3 categories: highly probable- clinical

range with score <50%, Borderline probable with score <50-60% and Normal with score >60%.

Diagnostic Domain	Clinical Range	Borderlines	Normal Range
Phonological Awareness	0-60%	60-70%	>70%
Reading Comprehension	0-50%	50-60%	>60%

Table8. score range

If a child's score is in the high probability range in both or in one diagnostic domain, it's considered highly probable for diagnosis of dyslexia.

When both score are in normal range, the child is not probable for dyslexia.

When child's score is in the borderline range in both or in one domain, it's classified as borderline dyslexic, which means that the child needs further clinical evaluation for comorbid disorders or needs a reevaluation in later developmental stages.

Finally, for limiting child's distraction to minimum level over tasks and help him remain focus during evaluation, the SGST's graphical interface should be 'static', with no music background and also adapted to children age.

2.1.2. Structure of the SGST

The SGST is consists of eight levels. Most of the levels correspond to subtests. We divided the optical discrimination of correct spelling words' subtest in two levels and we merge the 'metagnostic reading comprehension' subtest and the 'word supplementation in text' subtest in to one level.

Level	Subtest
level1	spelling
level2	the syllabic segmentation
level3	The small sentence comprehension
level4	the optical discrimination of correct spelling words
level5	syllabic word composition
level6	conception of left and right
level7	the optical discrimination of correct spelling words
level8	metagnostic reading comprehension - word supplementation in text

Table 9. mapping levels to subtest

The sequence of the levels is structured considering two parameters:

- a) The type of the activities of the level: we want to maintain the interest and the engagement of the user with a variety of activities (e.g. puzzles, drag and drop questions, multiple choice)
- b) The level of difficulty: a difficult activity is followed by an easier one giving the time to user to decompress.

Moreover, the sequence of the levels is linear. The user is not allowed to skip questions. The SGST ends when user complete all the levels of the game.

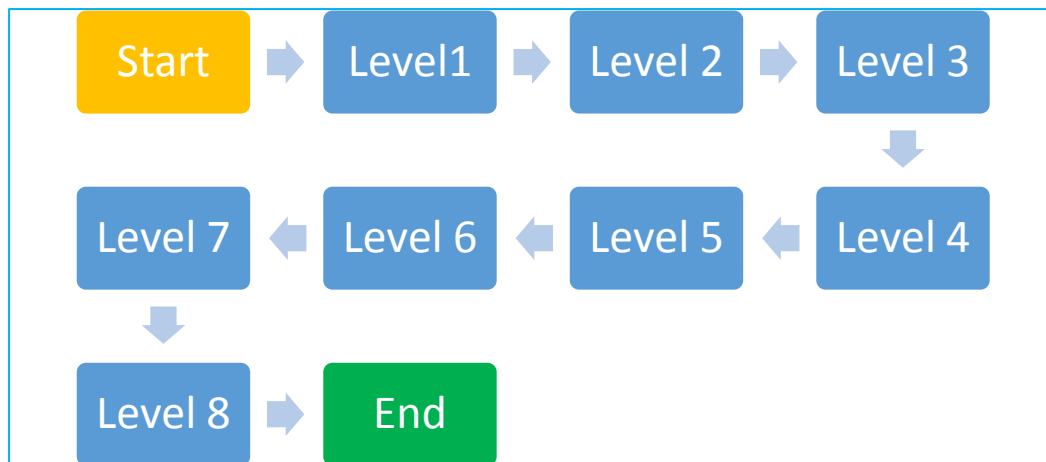


Fig10. Framework of the SGST

Finally, the SGST sends through email a detailed report with the answers and the results of the user and also connects with learning Locker LRS through xAPI.



Fig11. SGST's report results

2.1.3. Implementation of the SGST

2.1.3.1 Authoring Tool- iSpring Suite

We use iSpring Suite 8.5 (“iSpring,” n.d.) trial version for the implementation of the game. iSpring Suite is an authoring tool produced by iSpring for developing professional e-Learning courses with embedded (or standalone) quizzes, surveys, and interactions. Output is compatible with mainstream LMSs standards (SCORM/AICC) and xAPI (Tin Can). Output can be a solid SWF file(s), EXE file, HTML page or ZIP archive. Additionally, the cross-platform output format (Flash + HTML5) allows published content to work on desktops, laptops and mobile.

iSpring Suite helps to create quizzes for learning, knowledge check, and skill building. Perform accurate knowledge checks with versatile question types, from simple classics like multiple choice and matching to creative freeforms, hotspots, and word banks.

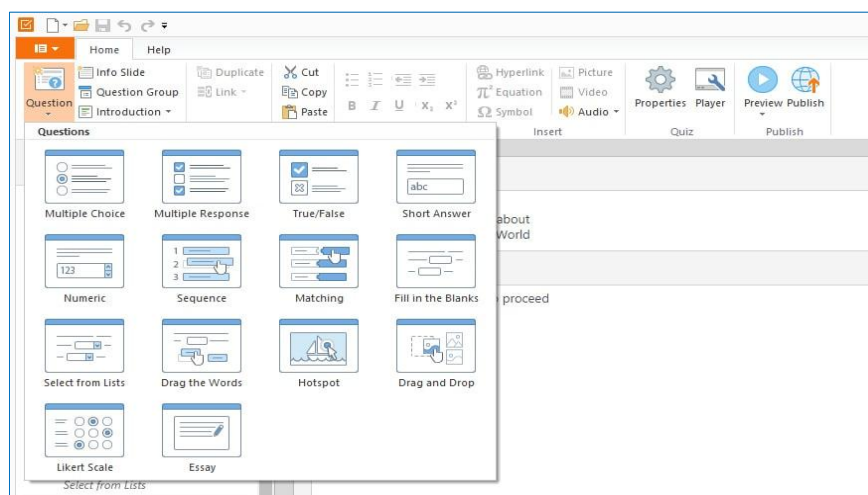


Fig12. iSpring Suite environment

2.1.3.2 Graphical user interface of SGST

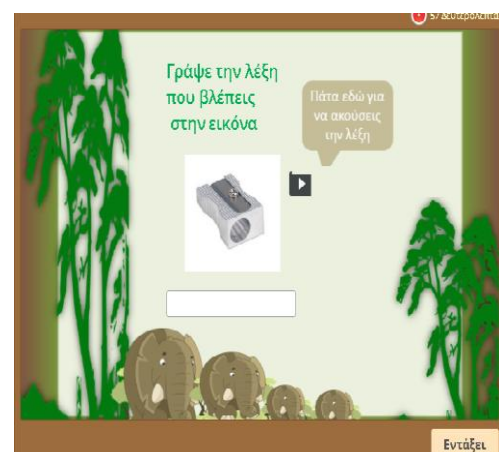
We described the structure of the game in previous section. Screen Shot 1 shows the eight levels of SGST. Each level represented with different animals. A squirrel indicates the position of the user during the game. Once a level complete turns to green. The game ends when squirrel – user complete all eight levels.

Photos, illustrations, vector and graphics we used in SGST is free of copyright most of them are downloaded from pixabay (<https://pixabay.com/>).



Screen Shot 1. Level of the SGST

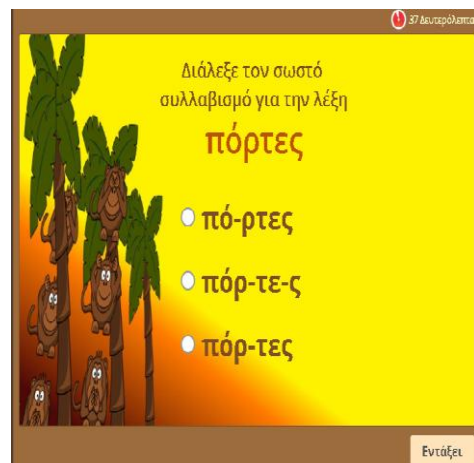
In level one- spelling subtest, the user has to write the word that is shown in the picture.



The user can hear the word by clicking the button. The format of the questions are type IN

Screen Shot 2. Level 1- spelling subtest

In level two- the syllabic segmentation, the player has a fixed amount of time to choose the correct answer. The type of questions are multipchoice.

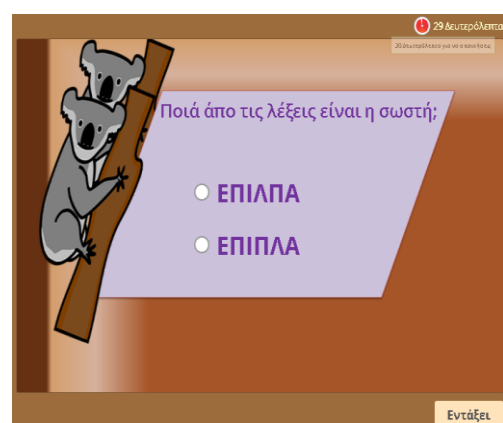


Screen Shot 3. Level 2- the syllabic segmentation

In level three - the small sentence comprehension, user has to choose the correct word for each sentence.

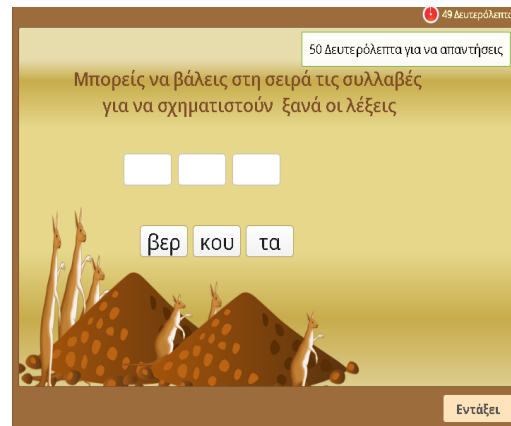


Screen Shot 4. Level 3- the small sentence comprehension



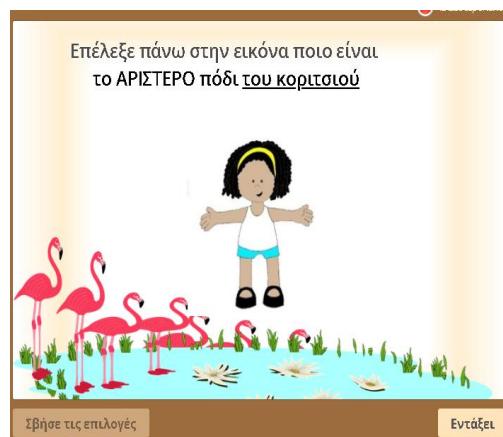
In level four - the optical discrimination of correct spelling words, user has to select the correct word.

Screen Shot 5. Level 4- the optical discrimination of correct spelling words



In level five - syllabic word composition, the user has to put the syllabus in correct order and form the word.

Screen Shot 6. Level 5- syllabic word composition



In level six, conception of left and right, we ask the user to locate a certain spot on the picture.

Screen Shot 7. Level 6- conception of left and right



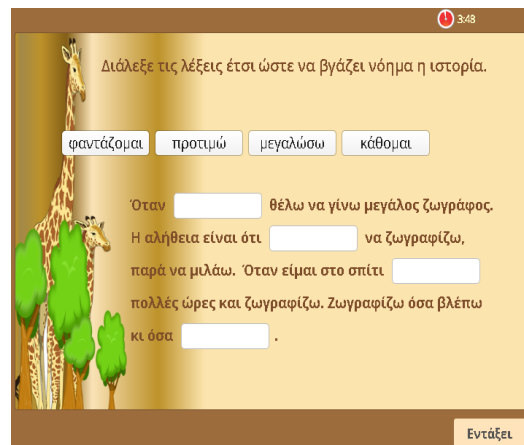
In level 7- part two of the optical discrimination of correct spelling words, user has to find the correct words

Screen Shot 8. Level 7- the the optical discrimination of correct spelling



In level eight- metagnostic reading comprehension, we ask the user to put in order the sentences and create a short story.

Screen Shot 9. Level 8- metagnostic reading comprehension



In level eight- word supplementation in text, the user has to read the text and choose the correct word for each gab.

Screen Shot 10. Level 8- word supplementation



Finally, before each level we provide the user with instructions and paradigms.

Screen Shot 11. Instructions before entering a level

The final version of SGST can run as a standalone on desktops and also as an application on tablets.

All of the game activities and questions are cited in the [Appendix 1](#) of this thesis.

2.1.4 Evaluation of the serious game from the experts.

After we completed the implementation of SG we gave it to 8 primary school teachers and 5 special need teachers for evaluation. They provide us with useful insights and suggestions which we took immediately into account.

All experts found the SG interesting. They liked the design of the SGST. They also made suggestions which we summarize as followed:

- a) A better sequencing of the levels of the game.
- b) Changing some words and sentences in activities.
- c) Improvement of the writing in instructions.
- d) Improvements regarding the graphical interface

Once the above-mentioned changes had been made, we proceeded to the creation of the new version of the SGST and we send it back to the experts for

further review. The last version of the SGST was generally proved with no further suggestions.

2.1.5. Pilot Test. Reliability and validity of the SG

In order to obtain information regarding the correct implementation of our tool and its reliability we carried out a pretest. We apply the SGST to 8 children of second grade (four boys and four girls) with no learning disabilities and also to 5 children (3 boys and 2 girls) with dyslexia. The aim of the pilot implementation was:

- a) to evaluate the engagement between children and the game.
- b) to record the response times to each activity.
- c) to define the scale scores, we use to evaluate the results.

After implementation all children expressed that they liked the graphical environment. They were motivated to answer the questions in order to move on to the next level. Moreover, they found most of the levels of the game easy and fun to play with.

Furthermore, observing the interaction of the children with the game we noticed that, we had to improve some instructions so that the children could have a better understanding of what they have to do.

Moreover, regarding the results, all the children with no learning disabilities passed successfully the test and all the children with dyslexia failed.

In addition, we set the time frame for each activity using the average response time of children with dyslexia and children without dyslexia needed to complete the activity.

Once the mentioned modifications and changes had been made we release the final version of the SGST. The final version of SGST can run as a standalone on desktops and also as an application to tablets.

2.2 Learning Locker LRS

2.2.1. Learning Locker Architecture Overview

Choosing an LRS to track our results was challenging. We tested free LRSs such as Watershed LRS, Saltbox's Wax LRS and Rustici's SCORM Cloud but all of them suffer of limitations. We end up using Learning Locker("Learning Locker," n.d.). Learning Locker is an open source LRS, xAPI ready and with advanced data cleansing, analysis and sharing tools.

Learning Locker is divided into two Github repositories, one for the Learning Locker application and one for the xAPI service. The Learning Locker application repository is made up of three parts (in the same Github repository), the browser interface (UI), the HTTP interface (API), and the workers. The three parts are running as their own process to share resources (since JavaScript is single-threaded) and ensure a degree of redundancy.

The xAPI service is made up of four services in separate Github repositories, the services are for statements, activity profiles, agent profiles, and state.

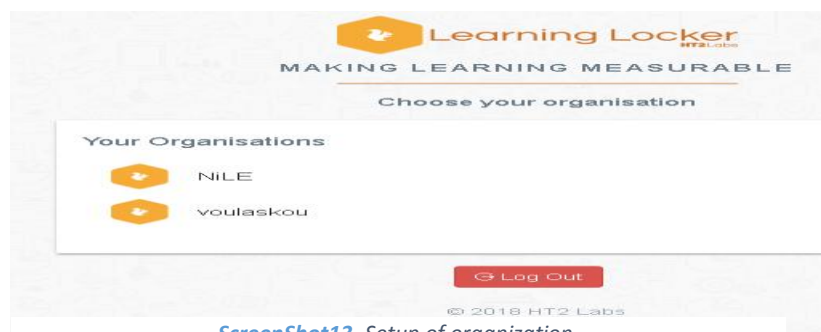
2.2.2. Installation of Learning Locker

At first, we installed Learning Locker version 2 in an Ubuntu Server virtual machine. We faced a lot of problems with the installation but finally we managed to setup the application.

App name	id watching	mode	pid	status	restart	uptime	cpu	mem	user
API	0	cluster	27555	online	0	6s	59%	148.1 MB	learningloc
UIServer	1	cluster	27561	online	0	6s	46%	119.2 MB	learningloc
Worker	2	cluster	27583	online	0	2s	86%	184.0 MB	learningloc

ScreenShot 12. Installing learning locker

As soon as we started testing the environment of learning locker we realized that our main problem was that we were using a virtual machine. We needed an Ubuntu server with a static ip address. We turn to the Natural Interaction LEarning Games Lab (NILE) that they were already running Learning Locker and they provide us access to their server. We setup our own organization "voulaskou". Organisations contain stores and clients inside learning locker.



ScreenShot13. Setup of organization.

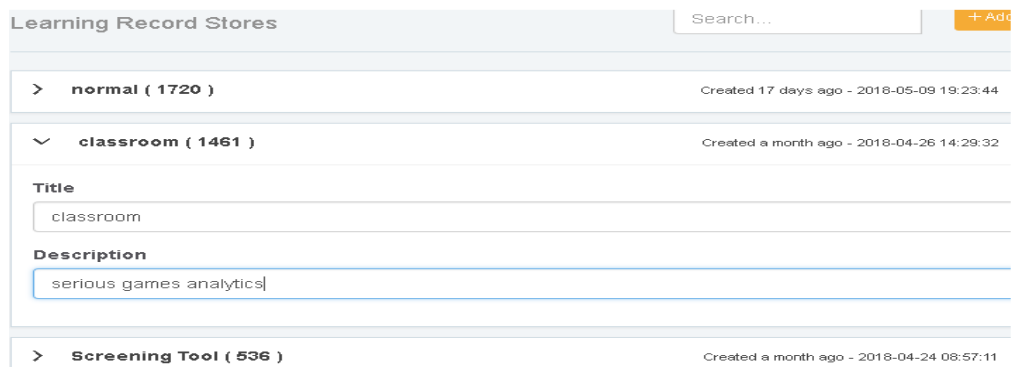
2.2.3. Structure of the LRS

In Learning Locker you can structure your organizations, stores, clients.

There are few key concepts

- Organizations contain stores and clients.
- Stores contain xAPI statements and xAPI documents.
- Clients can be used to access data within the organization via HTTP interfaces.
- Clients can be restricted to only access data within a single store in their organization.

Initially, we created a Learning Record Store 'classroom' where we could store our statements from the game.



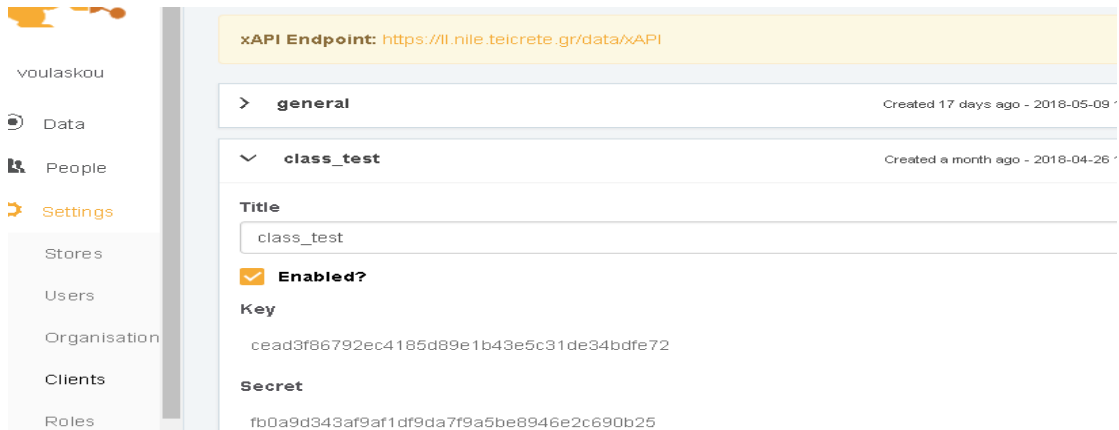
ScreenShot15. setup the Lrs

Afterwards, we setup the client which contains details for permissions, authenticating and storing the xAPI request from the game.

xAPI Endpoint: <https://ll.nile.teicrete.gr/data/xAPI>

Key : cead3f86792ec4185d89e1b43e5c31de34bdfe72

Secret : fb0a9d343af9af1df9da7f9a5be8946e2c690b25



ScreenShot 16. Create the client

2.2.4. Connect learning locker with SGST

As long as we created the client we connected the SGST. We established the connection by adding the following code inside the index.html file of SGST.

```
var params = {
  quizId: "dyslexia_screening_tool",
  flags: 3,
  resumeMode: "never",
  tincan:
  {
    endPoint: "https://ll.nile.teicrete.gr/data/xAPI/",
    auth:
    {
      type: "basic",
      key: "",
      login: "cead3f86792ec4185d89e1b43e5c31de34bdf72",
      password: "fb0a9d343af9af1df9da7f9a5be8946e2c690b25",
      name: "",
      email: ""
    }
  }
}
```

2.2.5. Managing Statements

Retrieving statements from SGST was a key point in our experiment. We describe in part one the way xAPI structures statements. We are [interested](#) in tracking not only results, but also which activities experienced, questions that answered or not answered, the time that took to complete the test.

Every answer, selection and action that a user makes in our game is captured by learning locker and saved in data/source section.

>	2019 completed	a day ago
	ispring://quizzes/dyslexia_screening_tool/groups/_38B60E98-D0EF-4DC3-8F48-CE0181514488_	
>	2019 failed DYSLEXIA SCREENING TOOL	a day ago
>	2021 answered	a day ago
	ispring://quizzes/dyslexia_screening_tool/questions/_79D56E1D-9EC2-43FE-A8CF-6213AA337ECB_	
>	2020 completed	a day ago
	ispring://quizzes/dyslexia_screening_tool/groups/_ED62E2D0-0915-4BD2-8CBF-A2A8E6FCB514_	

ScreenShot16. Statements of SGST 1

We described in previous section the scale we use to evaluate the results.

In order to analyze the results in learning locker we focused on the following

- a) if user passed the test.
- b) if user failed the test.
- c) if user is in border lines.
- d) how many completed the test
- e) average score of activities
- f) average score of diagnostic domains

And then we build queries in JSON to save these result statements.

For example, the query for users that failed the test is:

```

    {
      "$and": [
        {
          "$comment":
            "{\\"criteriaLabel\\":\\"F\\",\\"criteriaPath\\":[\\"statement\\",\\"verb\\"]}",
          "$or": [
            {
              "statement.verb.id": "http://adlnet.gov/expapi/verbs/failed"
            }
          ],
        },
        {
          "$comment": "{\\"criteriaLabel\\":\\"E\\",\\"criteriaPath\\":[\\"lrs_id\\"]}",
          "$or": [
            {
              "lrs_id": {
                "$oid": "5ae1b81cb4bd4b5e611cfc67"
              }
            }
          ],
        },
        {
          "$comment":
            "{\\"criteriaLabel\\":\\"G\\",\\"criteriaPath\\":[\\"statement\\",\\"object\\"]}",
          "$or": [
            {
              "statement.object.id": "ispring://quizzes/dyslexia_screening_tool"
            }
          ]
        }
      ]
    }
  ]
}

```

Also, we built the next query to track average result for each diagnostic

```

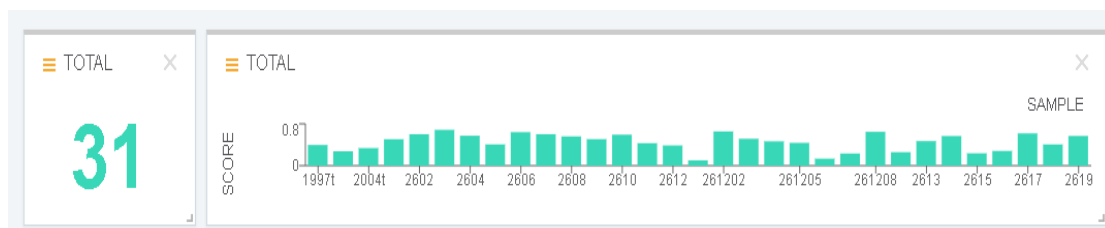
domain:
{
  "$and": [
    {
      "$comment": "{\\"criteriaLabel\\":\\"A\\",\\"criteriaPath\\":[\\"lrs_id\\"]}",
      "$or": [
        {
          "lrs_id": {
            "$oid": "5ae1b81cb4bd4b5e611cfc67"
          }
        }
      ],
    },
    {
      "$comment": "{\\"criteriaLabel\\":\\"B\\",\\"criteriaPath\\":[\\"statement\\",\\"object\\"]}",
      "$or": [
        {
          "statement.object.id": "ispring://quizzes/dyslexia_screening_tool/groups/_38B60E98-
D0EF-4DC3-8F48-CE0181514488_"
        },
        {
          "statement.object.id": "ispring://quizzes/dyslexia_screening_tool/groups/_ED62E2D0-
0915-4BD2-8CBF-A2A8E6FCB514_"
        }
      ]
    }
  ]
}

```

2.2.6. Virtualization of the results

Learning Locker is flexible enough to render many graph types such as bar charts, column charts, pie charts, scatter graphs. We use these graph types to virtualize our queries.

For example, we used the counter graph in order to virtualize the number of the participants in the experiment. Moreover, we used the column graph to virtualize participants' score and bar graph to optimize average score of diagnostic domain



ScreenShot17. Virtualization in learning

All queries, virtualizations are cited in [Appendix 3](#).

2.2.7. Learning Locker dashboard

Learning Locker allows users to create customizable dashboards using a WYSIWYG interface. Dashboards offer a way to group, organize and display the virtualizations. Each visualization is contained within a Widget, which you can organize and resize. Dashboards can also be shared, allowing to embed them in other sites, or just conveniently share certain Dashboards with others without them needed to log in or having access to your Learning Locker.

We set up two dashboards to organize our virtualizations. In the first one we display users' results and scores and in the other one we display more detailed analytics.

3. PART3- Experiment- Test

3.1. Experiment- Proceedings, sample, ethics, time

Proceedings

Five primary public schools of municipality of Herkalion, Crete were randomly selected. All schools were having Special Education Inclusion Classes.

The directors of schools were informed about the aim of our study and gave permission to implement the SGST to the children.

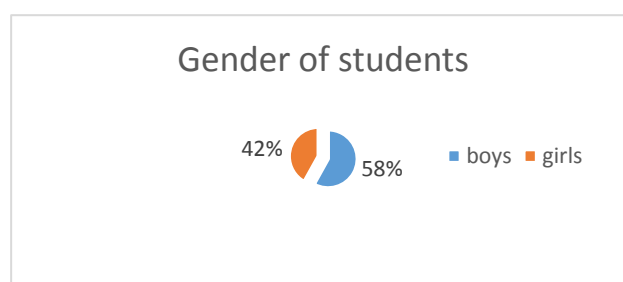
All special education teachers of the inclusion classes were trained in the SGST implementation.

ETHICS

Except from the gender of the participating children, additional personal data were not gathered in order to protect their anonymity.

SAMPLE

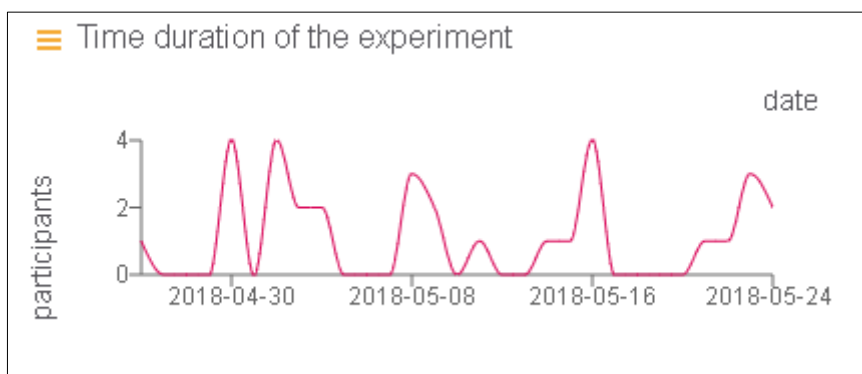
Our sample consisted of 31 second grade children, attending Special Education Classes. All children were previously diagnosed with dyslexia by public official diagnostic centers. Out of 31 children, 18 (58%) were boys and 13(42%) were girls.



Graph1. Distribution of sample according to gender

Time duration of the experiment

The experiment conducted from April 25TH until MAY 24TH of 2018. Graph1 shows the exact number of the participants who tested each day.



Graph.2 Time Duration of the experiment

3.2. Results

Among 31 participants, 29 (94 %) fulfilled the study criteria (Table 10). The 2 children who didn't fulfilled the study criteria were children who were receiving intensive special educational interventions since the first grade. Their scores though were slightly below the clinical borderline range.

SAMPLE			
TOTAL	Clinical Range	BORDER LINES	NORMAL
31	22	7	2
%	94%		6

Table10. Results of the participants.

Moreover, no significant differences were observed regarding the gender of the participants and performance in the test. Analytically, among 18 boys, 14 (77,78%) were in the clinical range, 2 (11,11%) in borderline range and 2 (11.11%) were in normal range. Furthermore, out of 13 girls, 8(62%) were in the clinical range and 5(%) in the borderline clinical range. Distribution of the sample according to gender and diagnostic category is depicted in [Table 11](#).

GENDER	CLINICAL RANGE		BORDERLINE RANGE		NORMAL RANGE		TOTAL	
	N	%	N	%	N	%	N	%
BOYS	14	77.78	2	11.11	2	11.1	18	58
GIRLS	8	62	5	38	0	0	13	42
TOTAL	22	71	7	23	2	6	31	100

Finally, no significant differences were observed regarding response times and the gender of the sample. The average time of completion of the SGST was 23min for boys and 25min for girls.

Table11. Distribution of sample according to gender

3.3. Learning Locker Analytics

More of SGST's data analysis performed in Learning Locker. Fig 12 is a screen shot of learning locker's dashboard. These are virtualizations of children's scaled scores which are classified by categories.



Fig 13. Learning Locker Dashboard-Score Results

Furthermore, Fig14 is a screen shot of learning locker dashboard and shows the average results of the participant in each diagnostic domain.

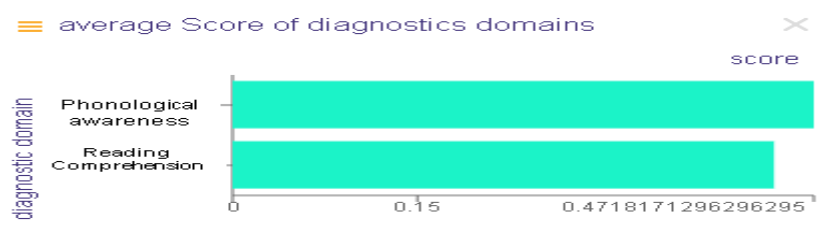


Fig. 13 Learning Locker Dashboard-Score of diagnostic domains

Finally, Fig 14 shows a part of the average score of children in each activity of SCGT. Table 12 derives from Learning Locker analytics and confirms the

validity of our initial classification regarding the level of difficulty for each activity.

Activity	Average Score Result
activity 10	0,89
activity 12	0,86
activity 28	0,75
activity 7	0,72
activity 29	0,72
activity 11	0,71
activity 15	0,69
activity 27	0,66
activity 18	0,65
activity 19	0,65
activity 9	0,64
activity 4	0,61
activity 8	0,6
activity 1	0,59
activity 13	0,57
activity 31	0,59
activity 20	0,54
activity 2	0,53
activity 16	0,52
activity 5	0,51
activity 30	0,51
activity 22	0,45
activity 25	0,45
activity 3	0,42
activity 17	0,41
activity 37	0,38
activity 36	0,36
activity 26	0,29
activity 14	0,29
activity 21	0,27
activity 35	0,26
activity 6	0,26
activity 23	0,25
activity 24	0,12

Table 12. Average score results per activity

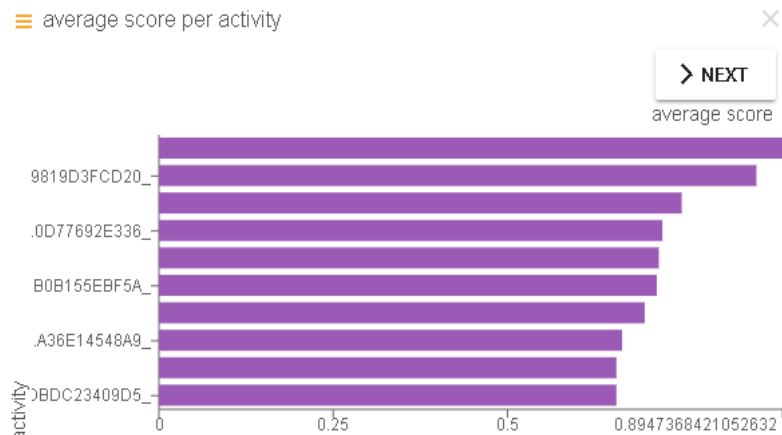


Fig 14. average score per activity

Conclusions

In this research we designed a serious game screening tool in order to identify children at risk for dyslexia at the end of 2nd grade and at the beginning

of 3rd grade. We tested the SGST to 31 children. We tracked SGST data through xAPI specification and we analyzed them in Learning Locker LRS.

The SGST test –experiment results were exceptionally good. We screened successfully 94% of the participants. Although, our results must be interpreted in the light of some limitations. The SGST test was implemented only to children with previous diagnosis of dyslexia. Standardization of the test in clinical and non-clinical sample is warrant, in order to draw firm conclusions about the validity and the reliability of the SCST. Moreover, interpretation of the results must be made with caution and in the light that they identify in the population children at risk for dyslexia, who need further assessment

Undoubtedly, ICT screening tools such as SGST, developmentally adapted and validated is feasible, can be used massive in schools, covering the existing lack of a school-based assessment. For Greek educational system, where many schools are isolated and the access to diagnostic centers is complicated and time-consuming, the use of ICT screenings tools would be beneficial for the child

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Appendices

Appendix 1. SGST 's implementation

Serious Game Screening Tool Implementation

Diagnostic Domain	Number of activities	Points	Time
A. Phonological Awareness	26	27	18min 30sec
B. Reading Comprehension	8	26	25min 30sec
C. Conception of left and Right	3	0	3min 30sec
Total	37	53	47min 30sec

A. Phonological Awareness Activities

The phonological awareness domain is comprised of 4 subtests: the spelling subtest, the syllabic segmentation subtest, the optical discrimination of correct spelling words subtest and the syllabic word composition subtest.

Number of activities: 26 Total Points:27 Time: 18min 30sec

A1- Subtest : spelling - Level 1

In level one- spelling subtest, the user has to write the word that is shown in the picture. Also, user can hear the word.

Activity 1.

Γράψε την λέξη

που βλέπεις

στην εικόνα

(Type: Type in, Points: 1,
Time: 1 min)



Acceptable answers
ξύστρα
ξίστρα
ξυστρα
ξιστρα
ξήστρα
ξηστρα
ΞΥΣΤΡΑ
ΞΙΣΤΡΑ
ΞΗΣΤΡΑ



Activity 2

Γράψε την λέξη

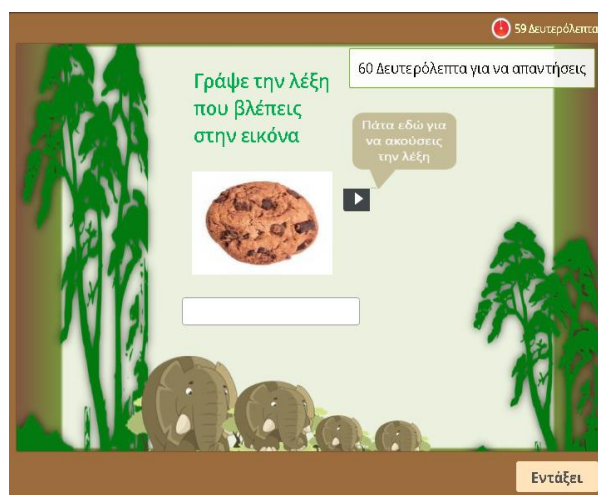
που βλέπεις

στην εικόνα

(Type: Type in, Points: 1,
Time:: 1min)



Acceptable answers
μπισκότο
μπισκοτο
ΜΠΙΣΚΟΤΟ



Activity 3

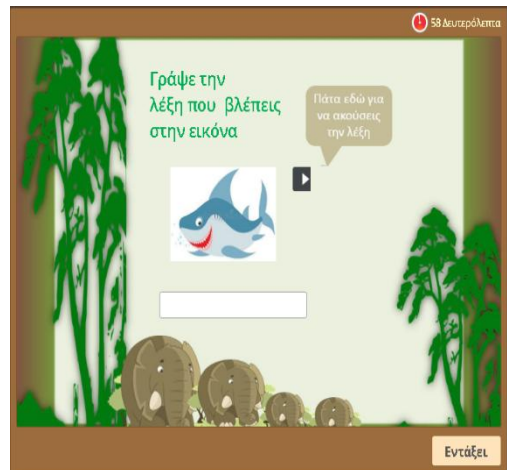
Γράψε την

λέξη που βλέπεις στην
εικόνα

(Type: Type in, Points: 1,
Time: 1min)



Acceptable answers
καρχαρίας
καρχαριας
ΚΑΡΧΑΡΙΑΣ



Activity 4

Γράψε την λέξη

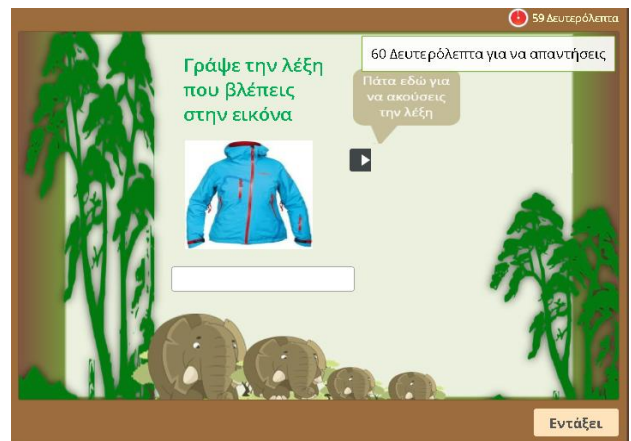
που βλέπεις

στην εικόνα

(Type: Type in, Points: 1, Time: 1min)



Acceptable answers
μπουφαν
μπουφάν
ΜΠΟΥΦΑΝ



Activity 5

Γράψε την λέξη

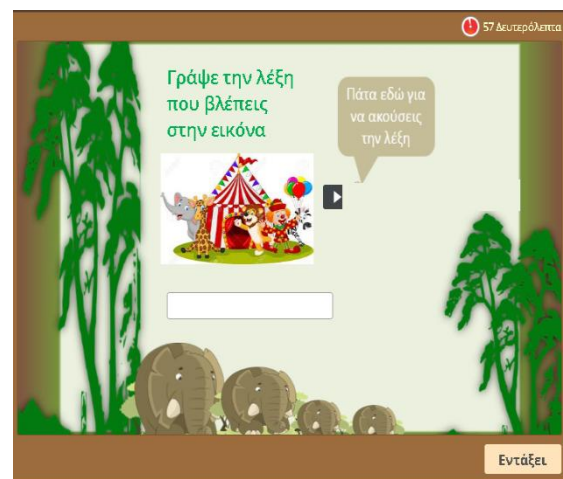
που βλέπεις

στην εικόνα

(Type: Type in, Points: 1, Time: 1)



Acceptable answers
τσιρκο
τσιρκο
ΤΣΙΡΚΟ



A2 – Subtest : syllabic segmentation - Level 2

In level two- the syllabic segmentation, the player has a fixed amount of time to choose the correct answer.

Activity 6

Διάλεξε τον σωστό συλλαβισμό για την λέξη

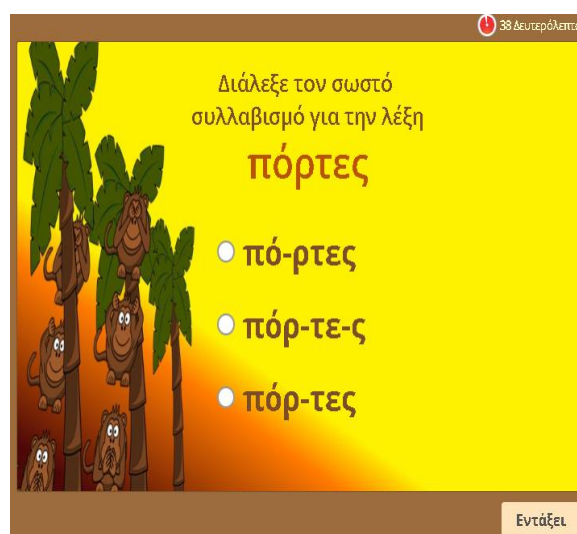
πόρτες

(Type: Multiple Choice, Points: 1, Time: 1min)

() πό-ρτες

() πόρ-τε-ς

(+) πόρ-τες



Activity 7

Διάλεξε τον σωστό συλλαβισμό για την λέξη

κεντρικός

(Type: Multiple Choice, Points: 1, Time: 1min)

(+) κε-ντρι-κός

() κεν-τρι-κός

() κε-ντρι-κό-ς

Activity 8

Διάλεξε τον σωστό συλλαβισμό για την λέξη

άνθρωπος

(Type: Multiple Choice, Points: 1, Time:1)

- () ά-νθ-ρω-πος
- (+) άν-θρω-πος
- () άνθ-ρω-πος



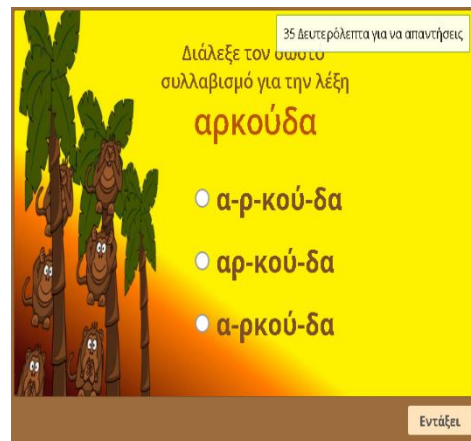
Activity 9

Διάλεξε τον σωστό συλλαβισμό για την λέξη

αρκούδα

(Type: Multiple Choice, Points: 1, Time: 1)

- () α-ρ-κού-δα
- (+) αρ-κού-δα
- () α-ρκού-δα



Activity 10

Διάλεξε τον σωστό συλλαβισμό για την λέξη

μπαστούνι

(Type: Multiple Choice, Points: 1, Time: 1min)

- (+) μπα-στού-νι
- () μπασ-του-νι
- () μπ-α-στού-νι



A3 – Subtest : syllabic segmentation - Level 4- Level 7

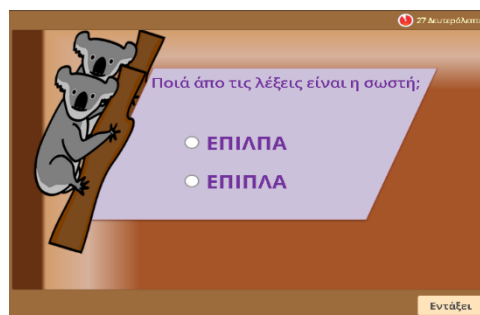
In level four - the optical discrimination of correct spelling words, user has to select the correct word

Activity 11

Ποιά από τις λέξεις είναι η σωστή;

(Type: True/False, Points: 0.5, Time:30sec)

- () ΕΠΙΛΠΑ
(+) ΕΠΙΠΛΑ



Activity 12

Ποιά από τις λέξεις είναι η σωστή;

(Type: True/False, Points: 0.5, Time:30sec)

- (+) ΚΑΠΝΟΣ
() ΚΑΝΠΟΣ

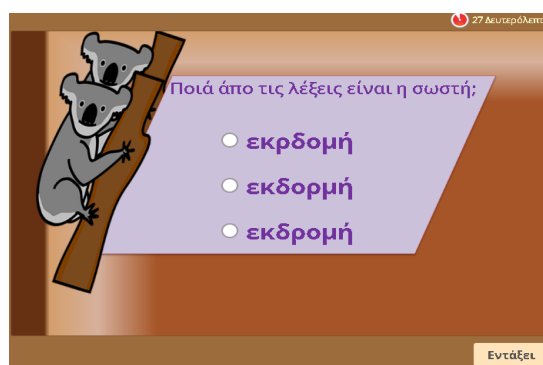


Activity 13

Ποιά από τις λέξεις είναι η σωστή;

(Type: True/False, Points: 0.5, Time:30sec)

- (+) ορκίζομαι
() οκρίζομαι



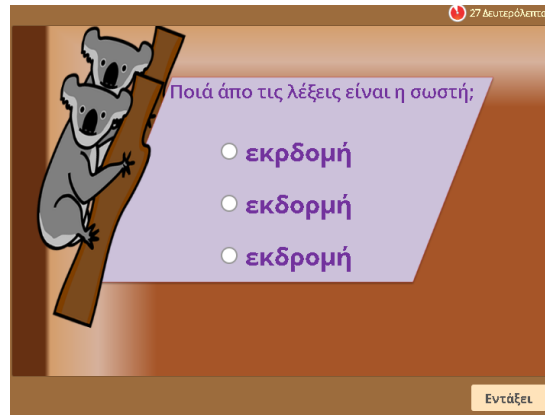
() οκίρζομαι

Activity 14

Ποιά άπο τις λέξεις είναι η σωστή;

(Type: True/False, Points: 0.5, Time:30sec)

- () εκρδομή
- () εκδορμή
- (+) εκδρομή

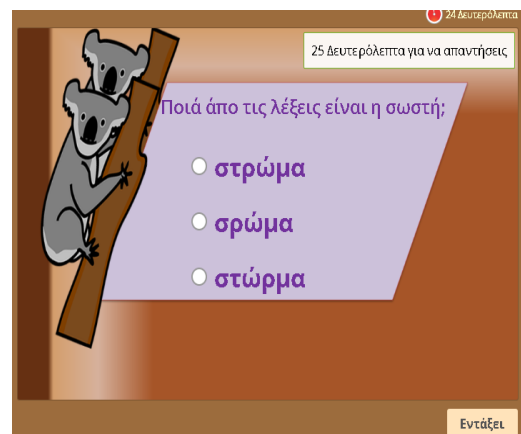


Activity 15

Ποιά άπο τις λέξεις είναι η σωστή;

(Type: True/False, Points: 0.5, Time:30sec)

- (+) στρώμα
- () σρώμα
- () στώρμα



Activiy 16

Ποιά άπο τις λέξεις είναι η σωστή;

(Type: True/False, Points: 0.5, Time:30sec)

- () ξύτρα
- (+) ξύστρα
- () ξύσρα



() κούστρα

Activity 17

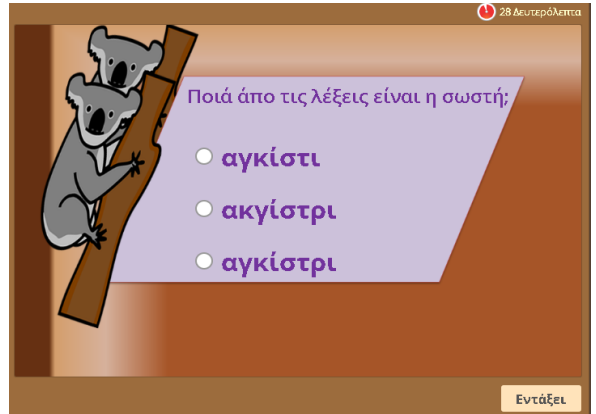
Ποιά από τις λέξεις είναι η σωστή;

(Type: Multiple Choice, Points: 0, Attempts: 1)

() αγκίστι

() ακγίστρι

(+) ακγίστρι



28 Δευτερόλεπτα

Ποιά από τις λέξεις είναι η σωστή;

- ακγίστι
- ακγίστρι
- ακγίστρι

Εντάξει

Activity 24

Επέλεξε τις λέξεις που είναι γραμμένες σωστά

(Type: Multiple Response, Points: 3, Time:2min)

[] συντορφιά

[] ξαλπώστρα

[+] συγκέντρωση

[+] ινδιάνος

[] πρεπατάς

[+] ελπίζω



1:57

Επέλεξε τις λέξεις που είναι γραμμένες σωστά

Περισσότερες από μια σωστές απαντήσεις

- συντορφιά
- ξαλπώστρα
- συγκέντρωση
- ινδιάνος
- πρεπατάς
- ελπίζω

Εντάξει

Activity 25

Επέλεξε τις λέξεις που είναι γραμμένες σωστά

(Type: Multiple Response, Points: 3, Time:2min)

[] ακγώνας

[+] αναπνοή

[+] διάβασμα

[] φλιτσάνι



1:29

Επέλεξε τις λέξεις που είναι γραμμένες σωστά

1 λεπτά 30 Δευτερόλεπτα για να απαντήσεις

από μια σωστές απαντήσεις

- ακγώνας
- αναπνοή
- διάβασμα
- φλιτσάνι
- έκκληθρο
- οπρέλα

Εντάξει

- [] έκληθορο
- [] οπρέλα

Activity 26

Επέλεξε τις λέξεις που είναι γραμμένες σωστά

(Type: Multiple Response, Points: 3, Time:2min)

- [+] διευθυντής
- [] περίεργος
- [] αλευθερία
- [+] ειδοποιώ
- [] παργματικά
- [] απόρσεκτος



A4 – Subtest : syllabic word composition - Level 5

In level five - syllabic word composition, the user has to put the syllabus in

Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις

correct order and form the word.

(Type: Word Bank, Points: 0,5,Time: 50sec)

Activity 18



κου βερ τα

Activity 19

Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις

(Type: Word Bank, Points: 0,5,Time: 30sec)

μπρα τσά κια

Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις

(Type: Word Bank, Points: 0,5,Time: 30sec)

συμ φω νώ

Activity 20

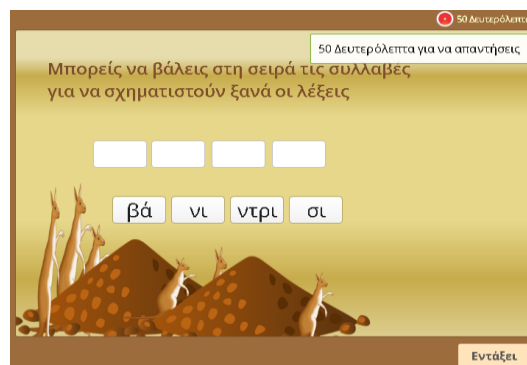


Activity 21

Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις

(Type: Word Bank, Points: 1,Time:50sec)

σι ντρι βά νι

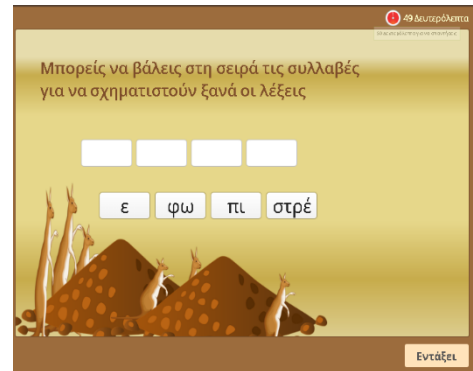


Activity 22

Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις

(Type: Word Bank, Points: 1, Time:50sec)

ε πι στρέ φω



Activity 23

Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις

(Type: Word Bank, Points: 1, Time:50sec)

οι νό πνευ μα



B Reading Comprehension Activities

The reading comprehension domain is comprised of 3 subtests: The small sentence comprehension subtest, the metacognitive reading comprehension subtest and the word supplementation in text subtest.

Number of activities: 8 Total Points: 26 Time: 25min 30sec

B1. Subtest : small sentence comprehension - Level 3

In level three - the small sentence comprehension, user has to choose the correct word for each sentence

Διάλεξε την σωστή λέξη για κάθε πρόταση

(Type: Multiple Choice Text, Points: 2, Time: 2,5min)

Κέρασα τους φίλους μου γλυκά (γλυκιά)

Η σοκολάτα είναι πολύ γλυκιά (γλυκά)

Οι μπάλες είναι λευκές (λεκές)

Η μπλούζα έχει έναν λεκέ (λευκέ)

28

Διάλεξε την σωστή λέξη για κάθε πρόταση

(Type: Multiple Choice Text, Points: 2, Time: 2,5min)

Ο βασιλιάς κάθισε στον θρόνο (θρόμο)

Τα παιδιά παίζουν στον δρόμο (θρόνο)

Στην γιορτή μου ήρθαν πολλά παιδιά (πόδια)

Η καρέκλα έχει τέσσερα πόδια (παιδιά)

Διάλεξε την σωστή λέξη για κάθε πρόταση

(Type: Multiple Choice Text, Points: 2, Time: 2,5min)

Σε παρακαλώ άναψε τα φώτα (φωτιά)

Οι πυροσβέστες έσβησαν την φωτιά (φώτα)

Θα κατέβεις στην αγορά (αγόρια) ;

Η τάξη έχει 11 αγόρια (αγορά)

Activity

27

Διάλεξε την σωστή λέξη για κάθε πρόταση

Κέρασα τους φίλους μου - -

Η σοκολάτα είναι πολύ - γλυκιά
- γλυκά

Οι μπάλες είναι - -

Η μπλούζα έχει έναν - -

Εντάξει

Activity

Διάλεξε την σωστή λέξη για κάθε πρόταση

Ο βασιλιάς κάθισε στον - -

Τα παιδιά παίζουν στον - -

Στην γιορτή μου ήρθαν πολλά - -

Η καρέκλα έχει τέσσερα - -

πόδια
παιδιά

Εντάξει

Activity 29

Διάλεξε την σωστή λέξη για κάθε πρόταση

Σε παρακαλώ άναψε τα φωτιά

Οι πυροσβέστες έσβησαν την φώτα

Θα κατέβεις στην αγορά ;

Η τάξη έχει 11 - -

αγορά
αγόρια

Εντάξει

Activity 30

Ταίριαξε τις προτάσεις με τις λέξεις

(Type: Multiple Choice Text, Points: 1.2, Time: 2min)

Τι θα κάνουμε αύριο. Έχεις καμιά	ιδέα
Δεν έχουν καμιά διαφορά. Είναι	ίδια
Για να βγούμε από την τάξη πρέπει να ζητήσουμε	άδεια

Βάλε στη σειρά τις προτάσεις

Activity 31

Αγόρασα μια ωραία	κούπα
Η βάρκα έχει	κουπιά
Βάλε τα παιχνίδια μέσα στην	κούτα

1:56

Ταίριαξε τις προτάσεις με τις λέξεις

Δεν έχουν καμιά διαφορά. Είναι

Τι θα κάνουμε αύριο. Έχεις καμιά

Για να βγούμε από την τάξη πρέπει να ζητήσουμε

Εντάξει

2:00

Ταίριαξε τις προτάσεις με τις λέξεις

2 λεπτά για να απαντήσεις

Βάλε τα παιχνίδια μέσα στην

Η βάρκα έχει

Αγόρασα μια ωραία

Εντάξει

B2. Subtest : metagnostic reading comprehension - Level 8

Ταίριαξε τις προτάσεις με τις λέξεις

(Type: Multiple Choice Text, Points: 1.2, Time: 2min)

create a short story.

metagnostic reading

comprehension, we ask the user to

put in order the sentences and

Activity 35

για να φτιάξεις την ιστορία

(Type: Matching, Points: 8, Time: 5 min)

1	Τίποτα δεν θα είχε συμβεί, αν δεν είχα πάει σ' αυτό το πάρτι
2	Δεν θα είχα σκοντάψει στην καρέκλα
3	Δεν θα είχα προσγειωθεί με τα μούτρα στην τούρτα του Βασιλή
4	και δεν θα με φώναζαν όλοι σήμερα, «τούρτα γενεθλίων»



B3. Subtest : word supplementation in text - Level 8

Word supplementation in text, the user has to read the text and choose the correct word for each gap

Διάλεξε τις λέξεις έτσι ώστε να βγάζει νόημα η ιστορία.

(Type: Word Bank, Points: 4, Time: 4min)

Όταν θέλω να γίνω μεγάλος ζωγράφος. Η αλήθεια είναι ότι να ζωγραφίζω, παρά να μιλάω. Όταν είμαι στο σπίτι πολλές ώρες και ζωγραφίζω. Ζωγραφίζω όσα βλέπω κι όσα .

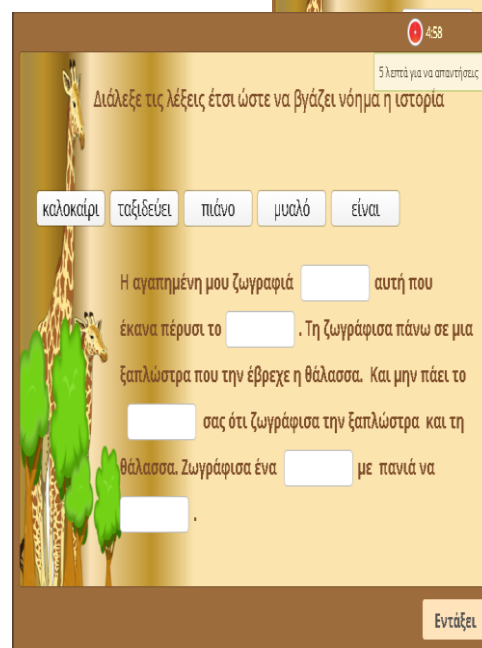
Activity 36



Activity 37

Διάλεξε τις λέξεις έτσι ώστε να βγάζει νόημα η ιστορία

(Type: Word Bank, Points: 5, Time: 5min)



Η αγαπημένη μου ζωγραφιά είναι αυτή που έκανα πέρυσι το καλοκαίρι. Τη ζωγράφισα πάνω σε μια ξαπλώστρα που την έβρεχε η θάλασσα. Και μην πάει το μυαλό σας ότι ζωγράφισα την ξαπλώστρα και τη θάλασσα. Ζωγράφισα ένα πιάνο με πανιά να ταξιδεύει.

C. Conception of Left and Right Activities

The left-right recognition domain has no predictive value in the test, although results can be included in the clinical picture of the child, as deficits in this domain often co-occur with dyslexia

Number of activities: 3 Total Points: 0 Time: 4min 30 sec

Activity 32

Επέλεξε πάνω στην εικόνα ποιο είναι

το ΑΡΙΣΤΕΡΟ πόδι του κοριτσιού

(Type: Hotspot, Points: 0, Time: 1,5min)

Hotspots: 1



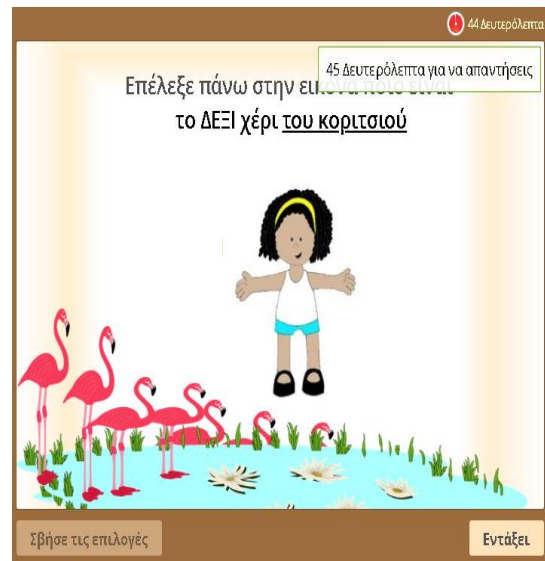
Activity 33

Επέλεξε πάνω στην εικόνα ποιο είναι

το ΔΕΞΙ χέρι του κοριτσιού

(Type: Hotspot, Points: 0, Time: 1,5min)

Hotspots: 1



Activity 34

Επέλεξε πάνω στην εικόνα ποιο είναι

το αριστερό χέρι του αγοριού

(Type: Hotspot, Points: 0, Time: 1,5min)

Hotspots: 1



Appendix 2. SGST's result report

This is the form of result report send through email

Dyslexia Screening Tool: "DYSLEXIA SCREENING TOOL"

ΟΝΟΜΑ: 2611 <el10@eleni.gr>

ΦΥΛΟ: ΚΟΡΙΤΣΙ

ΧΡΟΝΟΣ: 00:29:01 FROM∞

ΑΠΟΤΕΛΕΣΜΑΤΑ: **ΑΠΕΤΥΧΕ**

Αποτελέσματα ανά κατηγορία

Επιλογή	Το σκορ σου	Βασικό Σκορ	αποτελέσματα
group_1	45.56%	60%	✗
group_2	40.38%	50%	✗
1. Γράψε την λέξη που βλέπεις στην εικόνα ✔ Ξυστρα ΠΟΝΤΟΙ: 1/1 ΠΡΟΣΠΑΘΕΙΕΣ: 1/1			
2. Γράψε την λέξη που βλέπεις στην εικόνα ✔ Μπισκοτο ΠΟΝΤΟΙ: 1 / 1 ΠΡΟΣΠΑΘΕΙΕΣ: 1 / 1			
3. Γράψε την λέξη που βλέπεις στην εικόνα Δελφινι (καρχαρίας, καρχαριας, ΚΑΡΧΑΡΙΑΣ) ΠΟΝΤΟΙ: 0 / 1 ΠΡΟΣΠΑΘΕΙΕΣ: 1 / 1			
4. Γράψε την λέξη που βλέπεις στην εικόνα ✔ Μπουφαν ΠΟΝΤΟΙ: 1 / 1 ΠΡΟΣΠΑΘΕΙΕΣ: 1/1			
5. Γράψε την λέξη που βλέπεις στην εικόνα Καστρο (τσίρκο, τσιρκο, ΤΣΙΡΚΟ) ΠΟΝΤΟΙ: 0/1 ΠΡΟΣΠΑΘΕΙΕΣ: 1/1			
6. Διάλεξε τον σωστό συλλαβισμό για την λέξη πόρτες ✖ πό-ρτες			

πόρ-τε-ς

πόρ-τες

ΠΟΝΤΟΙ: 0/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

7. Διάλεξε τον σωστό συλλαβισμό για την λέξη κεντρικός

κε-ντρι-κός

κεν-τρι-κός

κε-ντρι-κό-ς

ΠΟΝΤΟΙ: 1/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

8. Διάλεξε τον σωστό συλλαβισμό για την λέξη άνθρωπος

ά-νθ-ρω-πος

άν-θρω-πος

άνθ-ρω-πος

ΠΟΝΤΟΙ: 0/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

9. Διάλεξε τον σωστό συλλαβισμό για την λέξη αρκούδα

α-ρ-κού-δα

αρ-κού-δα

α-ρκού-δα

ΠΟΝΤΟΙ: 0/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

10. Διάλεξε τον σωστό συλλαβισμό για την λέξη μπαστούνι

μπα-στού-νι

μπα-σ-του-νι

μπ-α-στού-νι

ΠΟΝΤΟΙ: 1/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

11. Ποιά από τις λέξεις είναι η σωστή;

ΕΠΙΛΠΑ

ΕΠΙΠΛΑ

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

12. Ποιά από τις λέξεις είναι η σωστή;

ΚΑΠΝΟΣ

ΚΑΝΠΟΣ

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

13. Ποιά από τις λέξεις είναι η σωστή;

ορκίζομαι

οκρίζομαι

οκίρζομαι

ΠΟΝΤΟΙ: 0/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

14. Ποιά από τις λέξεις είναι η σωστή;

εκρδομή

εκδορμή

εκδρομή

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

15. Ποιά από τις λέξεις είναι η σωστή;

στρώμα

σρώμα

στώμα

ΠΟΝΤΟΙ: 0/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

16. Ποιά από τις λέξεις είναι η σωστή;

ξύτρα

ξύστρα

ξύσρα

κούστρα

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

17. Ποιά από τις λέξεις είναι η σωστή;

αγκίστι

ακγίστρι

αγκίστρι

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

18. Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις
[κου] [βερ] [τα]

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

19. Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις
[τσά] (✓ μπρα) [μπρα] (✓ τσά) [κια]

ΠΟΝΤΟΙ: 0/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

20. Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις
[συμ][φω][νώ]

ΠΟΝΤΟΙ: 0.5/0.5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

21. Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις
[βά] (✓ σι)[ντρι] [νι] (✓ βά) [σι] (✓ νι)

ΠΟΝΤΟΙ: 0/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

22. Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις
[ε][πι][στρέ][φω]

ΠΟΝΤΟΙ: 1/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

23. Μπορείς να βάλεις στη σειρά τις συλλαβές για να σχηματιστούν ξανά οι λέξεις
[οι][πνευ] (✓ νό)[μα] (✓ πνευ) [νό] (✓ μα)

ΠΟΝΤΟΙ: 0/1 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

24. Επέλεξε τις λέξεις που είναι γραμμένες σωστά

- συντορφιά
- ξαλπώστρα
- συγκέντρωση
- ινδιάνος
- πρεπατάς
- ελπίζω

ΠΟΝΤΟΙ: 1/3 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

25. Επέλεξε τις λέξεις που είναι γραμμένες σωστά

- ακώννας
- αναπνοή
- διάβασμα
- φλιτσάνι

έκληθο

οπρέλα

ΠΟΝΤΟΙ: 1.2/3 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

26. Επέλεξε τις λέξεις που είναι γραμμένες σωστά

διευθυντής

περίεγρος

αλευθερία

ειδοποιώ

παργματικά

απόρσεκτος

ΠΟΝΤΟΙ: 0.6/3 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

27. Διάλεξε την σωστή λέξη για κάθε πρόταση

Κέρασα τους φίλους μου [γλυκά]

Η σοκολάτα είναι πολύ [γλυκιά]

Οι μπάλες είναι [λευκές]

Η μπλούζα έχει έναν [λευκές] (λεκέ)

ΠΟΝΤΟΙ: 1.5/2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

28. Διάλεξε την σωστή λέξη για κάθε πρόταση

Ο βασιλιάς κάθισε στον [θρόνο]

Τα παιδιά παίζουν στον [δρόμο]

Στην γιορτή μου ήρθαν πολλά [παιδιά]

Η καρέκλα έχει τέσσερα [πόδια]

ΠΟΝΤΟΙ: 2/2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

29. Διάλεξε την σωστή λέξη για κάθε πρόταση

Σε παρακαλώ άναψε τα [φώτα]

Οι πυροσβέστες έσβησαν την [φωτιά]

Θα κατέβεις στην [αγορά] ;

Η τάξη έχει 11 [αγόρια]

ΠΟΝΤΟΙ: 2/2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

30. Ταίριαξε τις προτάσεις με τις λέξεις

1. Τι θα κάνουμε αύριο. Έχεις καμιά

1. ιδέα

2. Δεν έχουν καμιά διαφορά. Είναι

2. ίδια

3. Για να βγούμε από την τάξη πρέπει να ζητήσουμε

3. άδεια

ΠΟΝΤΟΙ: 1.2/1.2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

31. Ταίριαξε τις προτάσεις με τις λέξεις

- | | |
|--------------------------------|-----------|
| 1. Αγόρασα μια ωραία | 1. κούπα |
| 2. Η βάρκα έχει | 2. κουπιά |
| 3. Βάλε τα παιχνίδια μέσα στην | 3. κούτα |

ΠΟΝΤΟΙ: 1.2/1.2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

32. Επέλεξε πάνω στην εικόνα ποιο είναι το ΑΡΙΣΤΕΡΟ πόδι του κοριτσιού

πόδι

ΠΟΝΤΟΙ: 0.2/0.2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

33. Επέλεξε πάνω στην εικόνα ποιο είναι το ΔΕΞΙ χέρι του κοριτσιού

Freeform 1

ΠΟΝΤΟΙ: 0.2/0.2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

34. Επέλεξε πάνω στην εικόνα ποιο είναι το αριστερό χέρι του αγοριού

Freeform 1

ΠΟΝΤΟΙ: 0.2/0.2 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

35. Βάλε στη σειρά τις προτάσεις για να φτιάξεις την ιστορία

- | | |
|------|---|
| 1. 1 | 3. Δεν θα είχα προσγειωθεί με τα μούτρα στην τούρτα του Βασίλη |
| 2. 2 | 2. Δεν θα είχα σκοντάψει στην καρέκλα |
| 3. 3 | 4. και δεν θα με φώναζαν όλοι σήμερα, «τούρτα γενεθλίων» |
| 4. 4 | 1. Τίποτα δεν θα είχε συμβεί, αν δεν είχα πάει σ' αυτό το πάρτι |

ΠΟΝΤΟΙ: 2/8 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

36. Διάλεξε τις λέξεις έτσι ώστε να βγάζει νόημα η ιστορία.

Όταν [προτιμώ] (✓ μεγαλώσω) θέλω να γίνω μεγάλος ζωγράφος. Η αλήθεια είναι ότι [κάθομαι] (✓ προτιμώ) να ζωγραφίζω, παρά να μιλάω. Όταν είμαι στο σπίτι [φαντάζομαι] (✓ κάθομαι) πολλές ώρες και ζωγραφίζω. Ζωγραφίζω όσα βλέπω κι όσα [μεγαλώσω] (✓ φαντάζομαι) .

ΠΟΝΤΟΙ: 0/4 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

37. Διάλεξε τις λέξεις έτσι ώστε να βγάζει νόημα η ιστορία

Η αγαπημένη μου ζωγραφιά [πιάνο] (✓ είναι) αυτή που έκανα πέρυσι το [μυαλό] (✓ καλοκαίρι). Τη ζωγράφισα πάνω σε μια ξαπλώστρα που την έβρεχε η θάλασσα. Και μην πάει το [καλοκαίρι] (✓ μυαλό) σας ότι ζωγράφισα την ξαπλώστρα και τη θάλασσα. Ζωγράφισα ένα [ταξιδεύει] (✓ πιάνο) με πανιά να [είναι] (✓ ταξιδεύει) .

ΠΟΝΤΟΙ: 0/5 | ΠΡΟΣΠΑΘΕΙΕΣ: 1/1

Appendix 3. Learning Locker

In this appendix we present all the queries we built in Learning Locker to help us analyze our data and classify our results.

1. Queries and Virtualization of scores of the participants

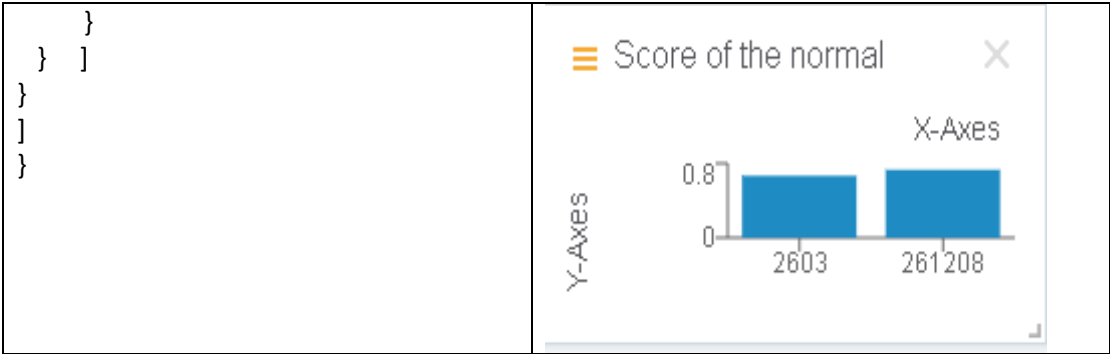
Score and number of all participants	
query	graph
<pre>{ "\$and": [{ "\$comment": "{\"criterionLabel\": \"D\", \"criteriaPath\": [\"statement\", \"verb\"]\", \"\$or\": [{ \"statement.verb.id\": \"http://adlnet.gov/expapi/verbs/completed }] }], { \"\$comment\": "{\"criterionLabel\": \"E\", \"criteriaPath\": [\"irs_id\"]\", \"\$or\": [</pre>	

<pre>{ "Irs_id": { "\$oid": "5ae1b81cb4bd4b5e611cfc67" } }] }]}</pre>	
Score and number of children in clinical range	
<pre>{ "statement.object.id": "ispring://quizzes/dyslexia_screening_tool/groups/_38B60E98-D0EF-4DC3-8F48-CE0181514488_" }, { "statement.object.id": "ispring://quizzes/dyslexia_screening_tool/groups/_ED62E2D0-0915-4BD2-8CBF-A2A8E6FCB514_" }] }, { "\$comment": "{ \"criterionLabel\": \"A\", \"criteriaPath\": [\"statement\", \"result\", \"success\"] }", "statement.result.success": false }] }</pre>	

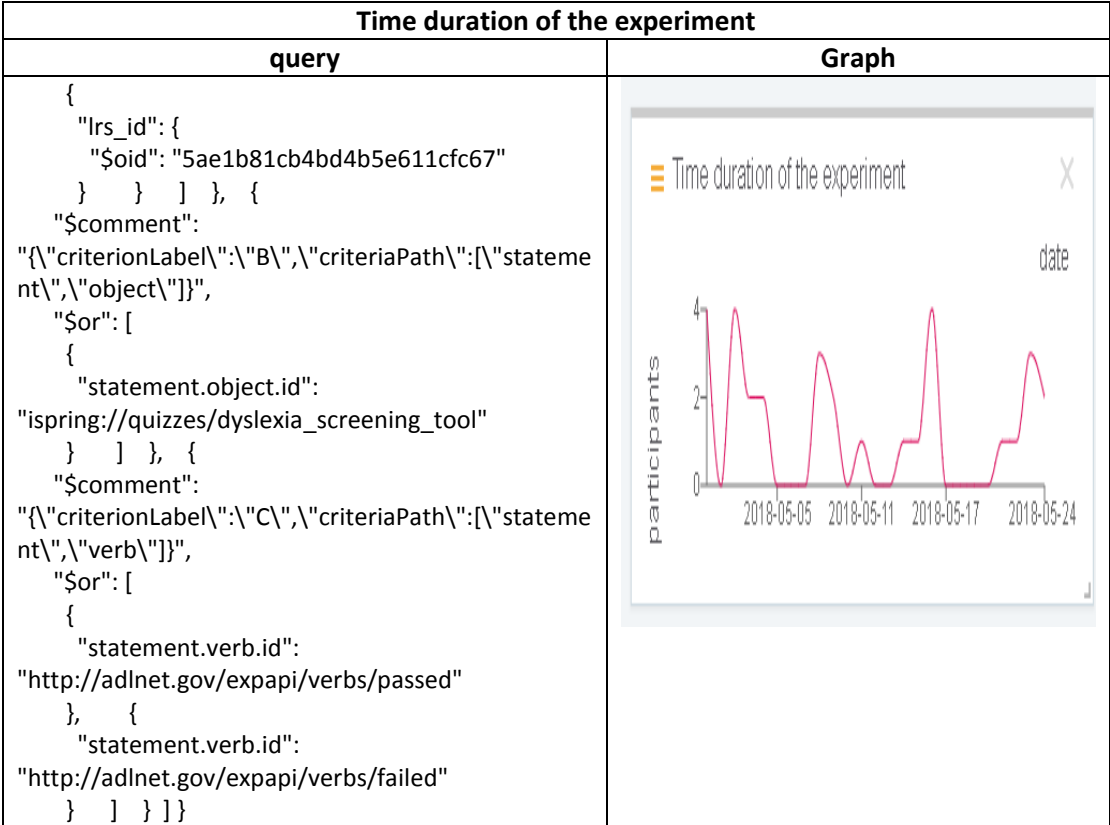
Score and number of children in border lines	
query	graph
<pre>{ "ispring://quizzes/dyslexia_screening_tool/groups/_ED62E2D0-0915-4BD2-8CBF-A2A8E6FCB514_" }] }, { "\$comment": "{ \"criterionLabel\": \"A\", \"criteriaPath\": [\"statement\", \"result\", \"success\"] }", "statement.result.success": true }, {</pre>	

<pre> "\$comment": "{\"criterionLabel\": \"A\", \"criteriaPath\": [\"statement\", \"result\", \"score\", \"scaled\"]}" , "statement.result.score.scaled": { "\$lte": 0.70 } }, { "\$comment": "{\"criterionLabel\": \"B\", \"criteriaPath\": [\"lrs_id\"]}" , "\$or": [{ "lrs_id": { "\$oid": "5ae1b81cb4bd4b5e611cfc67" } }] }, { "\$nor": [] } </pre>	<table border="1"> <caption>Score of the children in border lines</caption> <thead> <tr> <th>Child ID</th> <th>Score</th> </tr> </thead> <tbody> <tr> <td>2604</td> <td>~0.75</td> </tr> <tr> <td>2606</td> <td>~0.75</td> </tr> <tr> <td>2607</td> <td>~0.80</td> </tr> <tr> <td>2608</td> <td>~0.75</td> </tr> <tr> <td>2610</td> <td>~0.75</td> </tr> <tr> <td>261202</td> <td>~0.80</td> </tr> <tr> <td>2617</td> <td>~0.75</td> </tr> </tbody> </table>	Child ID	Score	2604	~0.75	2606	~0.75	2607	~0.80	2608	~0.75	2610	~0.75	261202	~0.80	2617	~0.75
Child ID	Score																
2604	~0.75																
2606	~0.75																
2607	~0.80																
2608	~0.75																
2610	~0.75																
261202	~0.80																
2617	~0.75																

Score and number of children who passed the text	
query	Graph
<pre> { "\$and": [{ "\$comment": "{\"criterionLabel\": \"D\", \"criteriaPath\": [\"statement\", \"verb\"]}" , "\$or": [{ "statement.verb.id": "http://adlnet.gov/expapi/verbs/passed" }]], { "\$comment": "{\"criterionLabel\": \"E\", \"criteriaPath\": [\"lrs_id\"]}" , "\$or": [{ "lrs_id": { "\$oid": "5ae1b81cb4bd4b5e611cfc67" } }] }] } </pre>	<p>number of normal</p> <p>2</p>

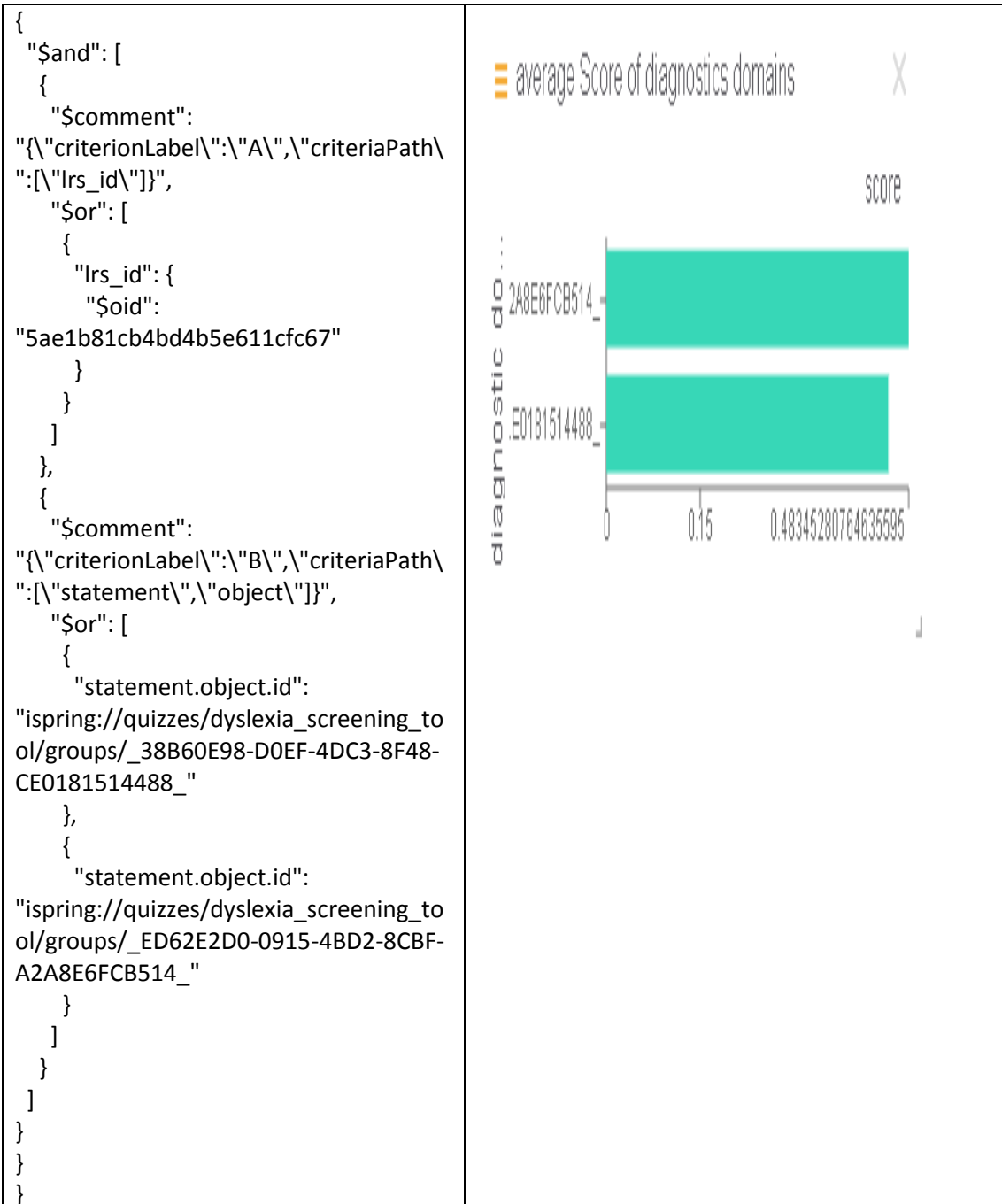


2. we set a query to track and virtualize the time duration of our experiment



3. we create a query to visualize the average score for each diagnostic domain.

Query	Graph



4. We built a query in order to optimize the average score for each activity in SGST

Average score foreach activity	
query	Graph

```

{
  "$and": [
    {
      "$comment":
      "{\\"criterionLabel\\":\\"
      "A\\",\\"criteriaPath\\":
      [\\"Irs_id\\"],"
      "$or": [
        {
          "Irs_id": {
            "$oid":
            "5ae1b81cb4bd4b5e
            611cfc67"
          }
        }
      ],
    },
    {
      "$comment":
      "{\\"criterionLabel\\":\\"
      "B\\",\\"criteriaPath\\":
      [\\"statement\\",\\"obj
      ect\\"],"
      "$or": [
        {
          "statement.object.id
          ":
          "ispring://quizzes/dy
          slexia_screening_too
          l/groups/_38B60E98
          -D0EF-4DC3-8F48-
          CE0181514488_"
        },
        {
          {
            "statement.object.id
            ":
            "ispring://quizzes/dy
            slexia_screening_too
            l/groups/_ED62E2D0
            -0915-4BD2-8CBF-
            A2A8E6FCB514_"
          }
        }
      ]
    }
  ]
}

```

