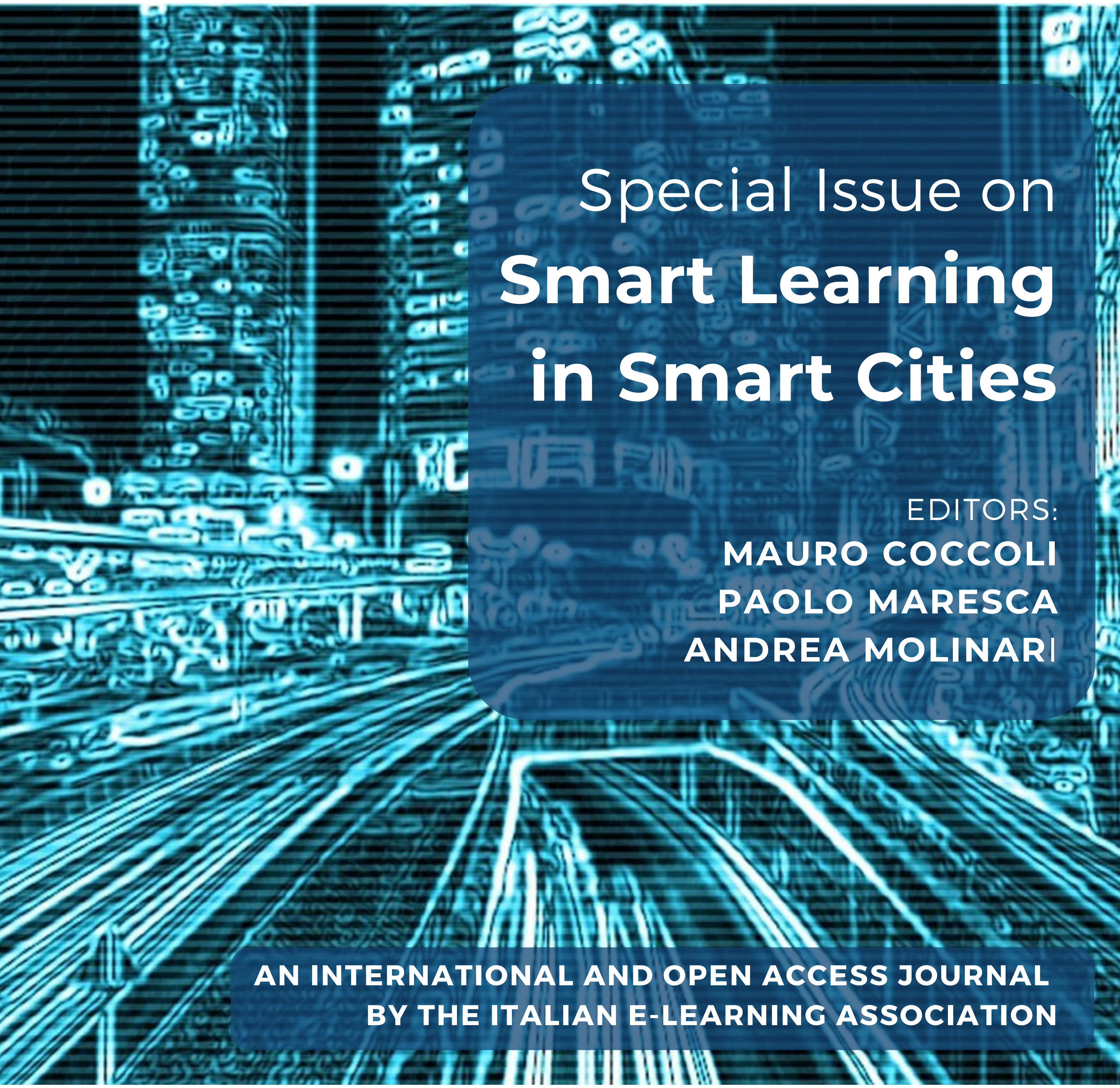
JOURNAL OF e-LEARNING AND KNOWLEDGE SOCIETY

www.je-lks.org

VOLUME 16 | ISSUE NO. 1 | APRIL 2020



Special Issue on
Smart Learning in Smart Cities

EDITORS:
MAURO COCCOLI
PAOLO MARESCA
ANDREA MOLINARI

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www.je-lks.org - www.sie-l.it

ISSN (online) 1971 - 8829 |ISSN (paper) 1826 - 6223

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The Journal is issued online three times per year.

ANVUR Ranking: A-Class for Sector 10, 11-D1 and 11-D2

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Italian e-Learning Association (SIe-L)

CONTACTS

editor@je-lks.org
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Registration at the Rome Court in the pipeline

ISSN (online) 1971 - 8829
ISSN (paper) 1826 - 6223

JOURNAL OF e-LEARNING AND KNOWLEDGE SOCIETY

www.je-lks.org

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EDITORIAL

Smart Learning in Smart Cities

Mauro Coccoli[a], Paolo Maresca[b], Andrea Molinari[c]
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DOI
https://doi.org/10.20368/1971-8829/1135258

CITE AS
Coccoli, M., Maresca, P., & Molinari, A. (2020). Smart Learning in Smart Cities [Editorial]. *Journal of e-Learning and Knowledge Society*, 16(1).

Commonly, the term *smart learning* is connected to the use of smart *learning environments*, with reference to the combination of software and hardware used for education and training by universities, schools, institutions and industries. In this field of application, in recent years, we have observed a never-ending succession of innovations in support of learning and instruction where instructional designers and developers run-after every new technology, to create innovative applications based on what they believe more effective, efficient, and engaging for both learners and teachers (Spector, 2014). Then, such software environments can be more or less smart, depending on the number and the quality of services offered and the capability of interacting with other systems. Another possible interpretation is to consider *smart learning* as learning *in smart environments* and, in this respect, Koper (2014) defines smart learning environments as physical places enriched with digital, context-aware and adaptive devices, which promote better and faster learning. For what concerns smart cities, we observe that they should be considered the most advanced implementations of smart environments, since they are plenty of physical devices and systems, used to provide citizens with highly effective services, to the aim of improving their quality of life. In fact, cities are smart when they fully exploit newly available smart technologies and smart solutions, which rely on most recent advancements in, e.g., big data, analytics, cloud architectures, artificial intelligence and cognitive computing. Moreover, recent modifications in both laws and policy, also driven by economics and market trends, are dramatically changing learning processes and environments in the universities so that students are regarded as customers and, consequently, the objective is enhancing their satisfaction, which can be achieved by improving the overall quality of services. Since the main task of schools and universities is education, we observe that their role in forming smart citizens, also contributing to enhance the individuals' quality of life, is of paramount importance. In conclusion, smart learning environments and smart cities adopt the same set of technologies and pursue the same objective of empowering people, thus, a new powerful educational ecosystem has to be considered, where learning involves students and teachers, which are primarily citizens.

In this ***Special Issue*** of the Journal of e-Learning and Knowledge Society, we focus on these aspects and we present both technical papers and surveys on education initiatives that follow the above-cited principles. In more detail, we report experiences on a variety of problems linked to the smart-factor in e-Learning and, in eight contributions, we illustrate a variety of points of view and different fields of application in different Countries.

L. Caviglione and M. Coccoli, in their *A holistic model for security of learning applications in smart cities* consider the idea of advanced learning frameworks that take advantages from the interconnection among individuals, multimedia artefacts, places, events, and physical objects that characterize any smart city. To do this, they consider smart cities as a playground plenty of data, which can be exploited to implement many learning activities. Given this scenario, the authors focus on the inherent privacy and security risks and introduce a model to help the engineering of novel learning frameworks for smart cities.

S. Siddiqui, M. Thomas, and N.N. Soomro, in their *Technology integration in education: source of intrinsic motivation, self-efficacy and performance,* investigate the effectiveness of a blended learning program through experimental setup in the South Asian context. The authors designed and tested a specific blended learning program for chemistry to the aim of enhancing their students' motivation. Based on the collected results, they found a significant and positive relationship between blended learning program, intrinsic motivation, self-efficacy, and academic achievements.

O.T. Adigun, in his *Computer-assisted instruction, project-based learning and achievement of deaf learners in biology*, determined the effect of computer-assisted instructions and project-based learning on academic achievement of deaf learners in biology, in Ibadan, Nigeria. The author found that computer-assisted instruction resulted more effective then problem-based learning, in enhancing achievement in biology among deaf learners. Therefore, biology teachers to deaf learners should adopt such technologies and methodologies to motivate and stimulate deaf leaners' interest in life sciences. Smart cities policies should be fair and inclusive and always try to overtake possible individual limitations.

A. Cadamuro and colleagues, in *Making the school Smart: The interactive whiteboard against disparities in children stemming from low metacognitive skills*, face the problem of providing differentiated education based on individual differences of children to stimulate effective learning. This can be achieved through smart devices such as interactive whiteboards. In their study, the authors tested the impact of new technologies and concluded that they can play an important role in supporting learning processes, especially of less metacognitive students, therefore contributing to reduce the gap between children with differential metacognitive skills.

F. Agrusti, M. Mezzini, and G. Bonavolontà, in their *Deep learning approach for predicting university dropout: a case study at Roma Tre University* consider the problem of dropout in tertiary education, which is a paramount topic in OECD Countries. Smart cities rely on both technology and smart policies, and, in this paper, deep learning is used to predict which student will likely dropout in Higher Education contexts, so to effectively launch targeted actions in order to limit such phenomenon.

E.W.F. Laksmi, Sarwanto and Chumdari, in their *Improving elementary school's critical thinking skills through three different PBL-assisted learning media viewed from learning styles*, analyze the differences in i) critical thinking skills among students provided with different learning media; ii) critical thinking skills among visual and auditory students; and iii) the interaction with the learning media. The investigation on such smart learning activities revealed that there are different skills in critical thinking in different learning media as well as some differences in critical thinking skills between visual and auditory students.

G. Albano and colleagues, in their *Technology to enable new paradigms of teaching/learning in mathematics: the digital interactive storytelling case*, propose another smart methodology implemented by means of a technology-enhanced learning activity designed specifically for learning/teaching mathematics, based on an interactive and immersive metaphor of storytelling. With their research, the authors aim to promote processes such as inquiring, conjecturing, formalizing, proving in mathematics, and to investigate which is the best way to organize smart solutions in smart schools, to achieve better results and improve performances.

A. Carbonaro, in her *Enabling smart learning systems within smart cities using open data*, highlights the opportunity to profitably exploit advanced solutions such as the linked open data platforms and automatic reasoning to effectively handle information and to use data linked queries in the domain of cognitive smart learning systems. Specifically, the author focuses on data availability to choose and develop interoperability strategies suitable for smart learning systems based on open standards and allowing seamless integration of third-party data and custom applications.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 01-10

A Holistic Model for Security of Learning Applications in Smart Cities

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(submitted: 28/10/2019; accepted: 11/02/2020; published: 30/04/2020)

Abstract

Modern learning frameworks take advantage of the interconnection among individuals, multimedia artifacts, places, events, and physical objects. In this perspective, smart cities are primary providers of data, learning stimuli and realistic hands-on laboratories. Unfortunately, the development of smart-city-enabled learning frameworks leads to many privacy and security risks since they are built on top of IoT nodes, wireless sensors networks and cyber-physical systems. To efficiently address such issues, a suitable holistic approach is needed, especially to reveal the interdependence between different actors, e.g., cloud infrastructures, resource-constrained devices and big data sources. Therefore, this paper introduces a model to help the engineering of novel learning frameworks for smart cities by enlightening the problem space characterizing security.

KEYWORDS: e-learning, smart cities, privacy and security, big data, model-driven design

DOI
https://doi.org/10.20368/1971-8829/1135031

CITE AS
Caviglione L., Coccoli M., (2020) A holistic model for security of learning applications in smart cities.Journal of E-Learning and Knowledge Society, 16(1), 01-10. https://doi.org/10.20368/1971-8829/1135031

1. Introduction

The implementation of the smart city paradigm requires deploying emergent technologies to better manage the finite resources of modern urban areas (Allwinkle & Cruickshank, 2011). In essence, the main goal of a smart city is the enhancement of the quality of life of citizens, mainly by optimizing aspects related to healthcare, bureaucracy, public transportation and commerce, just to mention some. To pursue such vision, relevant advancements in several fields are required, including ICT, humanities and social sciences, architecture and environment protection.

With reference to our country, one of the most important drivers to pursue the smart city vision is the European Union. In fact, its policies provide several funding schemes to improve nine dimensions defining the quality of life, which complete the more aseptic gross domestic product indicator used to measure the economic and social development of a country. However, the dimension of education has been often neglected in favor of environmental challenges, pollution prevention, energy efficiency, and safety. Indeed, smart cities and learning can be merged as to pursue new, interactive and efficient frameworks. This requires bringing both learners and learning platforms into an interactive environment populated with wireless sensors, portable devices, and nodes of the IoT. Alas, the pervasive nature of smart paradigms demands for mechanisms to handle user mobility, manage big data sources, offload devices with constrained capabilities, and mitigate communication issues due to intermittent network coverage (Caviglione, 2006).

In such a scenario, privacy and security of the entire architectural blueprint become critical aspects, which are the topics of this paper. In fact, the perception of a

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"secure" environment is crucial for its acceptance. As an example, see the work by Wilkowska and Ziefle (2011) for a detailed study on the case of medical assistive technologies. Unfortunately, guaranteeing the security and privacy of users requires searching for a complex and fragile trade-off. For instance, learners cannot be completely anonymous and some information about their actions should be collected by the platform or by the supervisor in order to evaluate progresses, adapt the learning curve and draw reasonable assessments (Borcea et al., 2005). Moreover, the increasing personalization of the learning experience by means of big data sources, possibly enriched with bits gathered from social media, may open several opportunities to undertake attacks via social engineering techniques (Manca et al., 2016).

Even if issues caused by the merge of learning platforms with smart city environments have not been explicitly discussed in the literature, several works already investigated trust, privacy and security features of e-learning frameworks. For instance, Anwar and Greer (2012) focused on trust, which is a core aspect for distance learning or for remotely interact with the software artifacts provided by a smart city. In fact, while in a classroom the authenticity is guaranteed by the physical presence, in a virtualized environment, other techniques have to be used. The work of Caviglione and Coccoli (2018) deals with smart learning platforms fed with big data generated by sensors, buildings and appliances deployed in a smart city, but does not offer a solution to protect the bulk of information or to prevent security flaws caused by improper access rights, incorrect mappings and conversions, de-anonymization attacks and steganographic threats. A possible solution is to deploy some layers for removing personal information, promote privacy awareness and provide context separation (Anwar et al., 2006). Alas, this is not a trivial task, especially in smart cities, where data are provided by different, heterogeneous sources and the volumes of information could not allow a fine-grained management (Hashem et al., 2016).

Even if limited to legacy client-server frameworks, Miguel et al. (2012) discuss requirements to avoid attacks like spoofing, unauthorized accesses, fraudulent alteration of learning materials, injection of virus or malicious code, and Denial of Service (DoS). The work of Bdiwi et al. (2018) partially addresses smart cities as it investigates intelligent classrooms equipped with IoT nodes, smart devices and connected objects. In essence, authors propose to use blockchain technologies to guarantee security and authenticate data as to prevent misuses and attacks. A specular problem, i.e., authenticating users, is addressed by Kang and Kim (2015).

Concerning mobile and ubiquitous frameworks, the work of Kambourakis (2013) surveys several security and privacy issues of mobile-learning and ubiquitous-learning, but does not cover the use of smart or emerging paradigms, such as the Bring Your Own Device (BYOD) one (Miller et al., 2012). Lastly, the work of Neila and Rabai (2014) proposes a matrix-driven design approach to quantify the security issues of e-learning platforms, especially technology-dependent attacks, such as cross site request forgery, buffer overflows and DoS.

To sum up, all the aforementioned works do not consider the issues, both in terms of security hazards or privacy leaks, arising from the use of smart cities to enhance learning frameworks. Additionally, the resulting complexity demands for a holistic approach, instead of solely considering an aspect at time, e.g., the guest operating system running core services or the user behavior. In this perspective, along the lines of Caviglione et al. (2014), this work introduces a holistic model to describe the privacy and security issues characterizing cutting-edge learning applications leveraging smart cities. In this respect, Zuev (2012) proposes a model for e-learning systems but it concentrates on the didactic risk, and hazards caused by the learning material and the delegation of responsibility from the teacher to the electronic Learning Management System (LMS). Thus, at the best of the authors' knowledge, this is the first work dealing with security aspects of e-learning exploiting smart cities.

The main contributions of this work are: *i)* a model to classify and organize security and privacy aspects of the joint use of smart city and learning environments, and *ii)* a methodology to isolate hazards of future learning applications and to reveal new ones.

The remainder of the paper is structured as follows. Section 2 presents the proposed functional model. Section 3 deals with learner space, Section 4 discusses the hazards caused by data, and Section 5 showcases risks due to the mix of technologies implementing the learning infrastructure and the smart city. Section 6 provides examples on how to exploit the modeling approach, while Section 7 concludes the paper and proposes some possible future extensions.

2. Privacy and Security: A Holistic Model

As hinted, the interplay among social, educational and technological aspects characterizing learning applications in smart cities leads to a very composite set of privacy and security issues. To understand and enlighten possible cause-effect relations including potential hazards, we introduce the model illustrated in Figure 1.

As depicted, each space contains a homogenous set of entities implementing coherent and recognizable

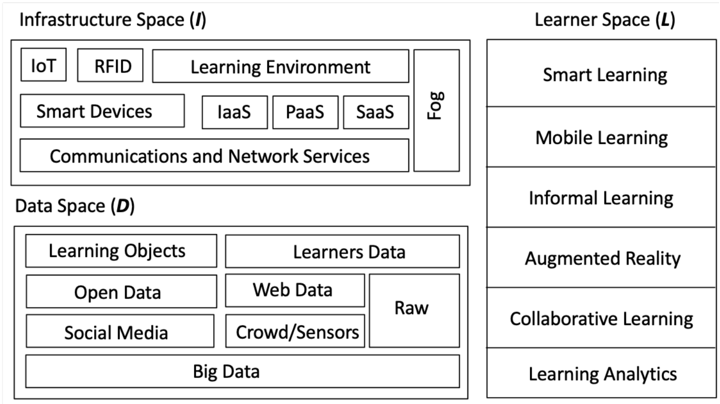

Figure 1 – The three spaces characterizing learning applications in smart-city environments.

aspects of the learning process. For the sake of clarity, Figure 1 only contains the most popular architectural components and technologies as well as learning models. Each space should be considered as a sort of base, which can be used to describe privacy and security within a well-given functional scope. In more detail, the model is articulated as follows:

- **Infrastructure Space**: it groups all the software and hardware entities composing the smart-city-learning paradigm, i.e., from user devices to server farms. In general, the resulting space is highly composite and complex as modern learning frameworks support on-the-road and hands-on didactics, hence mixing many technologies, including wireless communications, mobile agents, and cloud architectures (Caviglione et al., 2011a).
- **Data Space**: it groups all the functionalities related to the creation, collection, processing and storage of data. It considers issues ranging from those characterizing standard learning objects to leakage of information in social network sites and Intelligent Tutoring Systems (ITS) as well (Riccucci et al., 2007). This space also describes attacks that can be developed by considering novel sources, such as those exploiting unknown relations nested within big data (Bertino & Ferrari, 2018) or weaknesses of crowd-based schemes collecting measures from the field (Ganti et al., 2011).
- **Learning Space**: it groups the different learning methodologies that can be used in the smart-city-capable scenario. For instance, it considers issues arising from interlinking of learning resources (Carbonaro, 2012) or from "interpersonal" relations, like bullying, lack of anonymity or the need of enforcing a rigorous execution of assessments (Marais et al., 2006).

The three aforementioned spaces can be used as "bases" to describe the security and privacy features of learning applications in a holistic manner. For instance, an unsecure wireless channel could allow to collect insights from the data space or to infer some habits of the learner. Similarly, the data space can be used to attack the learner, even physically, e.g., by disclosing his/her geographical location. Another example deals with implementation-specific issues such as Web-based technologies prone to weaknesses identified by the Open Web Application Security Project, or misconfigured databases vulnerable to SQL injection (Caviglione et al., 2014).

To discuss such relationships and dependencies, let us denote with $\boldsymbol{I}$, $\boldsymbol{D}$, and $\boldsymbol{L}$ the infrastructure, data, and learning space, respectively. Each one represents a collection of hazards related to the specific technological components of that space. More precisely, $\boldsymbol{I}=\{i_1, i_2, \ldots, i_N\}$, $\boldsymbol{D}=\{d_1, d_2, \ldots, d_M\}$, and $\boldsymbol{L}=\{l_1, l_2, \ldots, l_K\}$, where N, M, and K are the amount of threats of each space. Vulnerabilities of $\boldsymbol{I}$, $\boldsymbol{D}$, and $\boldsymbol{L}$ have to be addressed during the design and engineering of the learning application or mitigated at runtime with proper countermeasures.

The interplay of the various techniques will result into a complete security and privacy space denoted with $\boldsymbol{C}$ and defined as:

$$\boldsymbol{C} = f(\boldsymbol{I}, \boldsymbol{D}, \boldsymbol{L}),$$

where, $f(\cdot)$ is a design-dependent function. Unfortunately, defining a unique $f(\cdot)$, possibly analytical, could be unfeasible, but some relations can be empirically derived (Ten et al., 2010). Instead, we aim at defining a framework for quantitatively investigate vulnerabilities. Let us introduce with $|\cdot|$ a pseudo-cardinality operator, i.e., a measure of the impact of all the components of a space. As discussed by Caviglione et al. (2014), the complex mix of behaviors of learners, smart environments and ICT techniques can "amplify" the number of hazards and weaknesses of the entire framework. The combination of multiple vulnerabilities across different spaces can cause new threats, i.e.:

$$|\boldsymbol{C}| \geq |\boldsymbol{I}| + |\boldsymbol{D}| + |\boldsymbol{L}| \quad (1)$$

By defining $|\boldsymbol{C}| = J$, Equation (1) leads to $J \geq N+M+K$. To clarify this, let us introduce a toy example considering a learning application enhanced via social media. A possible visual representation can be obtained by using alluvial diagrams as depicted in Figure 2 showcasing the mappings of security risks for each space.

According to our model, Figure 2*a* shows that both learner and data spaces are characterized by five different vulnerabilities or attacks, hence $K=M=5$, whereas the infrastructure space is characterized by $N=4$. We point out that not all the vulnerabilities can be feasible for an attacker, e.g., due to a lack of skills. However, when blended in the learning application, an attacker can "move" through spaces to find an exploitable vulnerability. As an example, penetrating into a host to exfiltrate sensitive data requires to being able to attack the $\boldsymbol{I}$ space, i.e., to void the security framework of the operating system. The attacker can act on $\boldsymbol{D}$ by collecting data from social media and obtain sensitive bits via social engineering on $\boldsymbol{L}$. The leaked information can be used to craft a dictionary to make password cracking feasible (Bonneau, 2012), hence granting access to an inaccessible i-th component of the $\boldsymbol{I}$ space as shown in Figure 2*b*. We point out that this corresponds to mix different privacy and security threats and leads to an attack only feasible in the space $\boldsymbol{C}$. In our model, this is quantitatively denoted as considering J=15, which is greater than the sum of the pseudo-cardinality of each space owing to the password cracking attack. In real-world usages, J should be considered as a sort of weight, rather than a strict indicator of the number of real vulnerabilities. In fact, precisely enumerating all the threats affecting a given module or technology is usually unfeasible. In practice, at design time, J has to be considered carefully by both instructional designers and developers. It can help to quantify the (in)security of the applications and, for example, reserve an adequate budget.

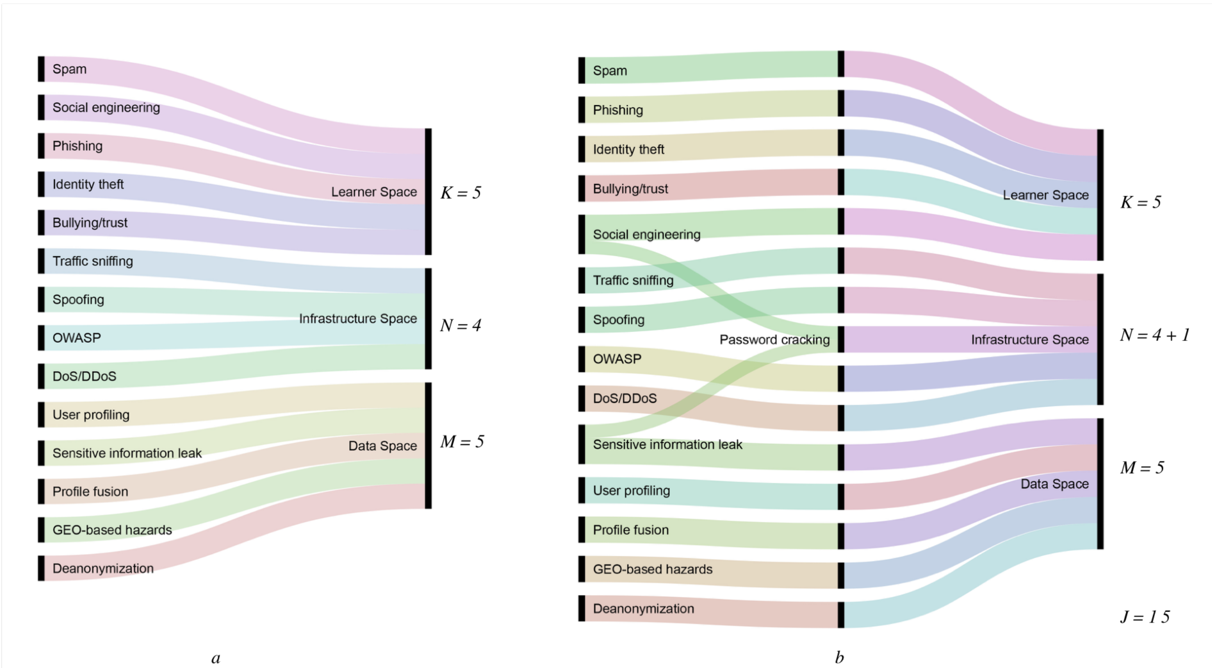

Figure 2 – Toy example: the different security issues in the relevant spaces.

In the following, we will characterize each space by surveying the related literature with emphasis on hazards addressing the joint usage of learning applications and smart city technologies. For the sake of brevity, this paper does not cover "plain" cybersecurity threats, which have been already investigated, see, e.g., the recent work by Humayed et al. (2017) on issues of cyber-physical systems and IoT technologies.

3. Learner Space

The learner space ***L*** is where the learning process happens. It can rely upon mobile and ubiquitous learning paradigms as well as lifelong learning strategies, or exploit novel solutions such as augmented reality.

Even if not specifically addressing a smart city scenario, the work by Bellekens et al. (2016) confirms that the majority of e-learning users do not have a clear understanding of risks and threats associated with the use of computing and network technologies. This may lead to major pitfalls, as users can be prone to social engineering attacks, poorly configure their accounts, introduce additional fragilities due to a BYOD policy or being target for technology-specific attacks as it happens in developing countries where satellites are often used (Caviglione, 2009).

Scientific training is a very important application of e-learning and can show major benefits if applied to smart cities, as they offer the access to complex infrastructures, collections of raw data coming from the field as well as the possibility of observing cause-effect relations, e.g., the trend of temperature and humidity in a building when parameters of heating, ventilation and air conditioning plants are changed. However, data must be protected with policies to guarantee the ownership while enabling some form of linkage and archiving (Demchenko et al., 2013).

An important advancement made possible by IoT technologies concerns the case-based learning and its pollination with flipped learning approaches. The smart city offers a wide variety of use-cases helping students to evaluate data and draw conclusions. This, for instance, can be the scenario of using measurements from IoT nodes to investigate the impact of pollutants on the health of citizens. To this aim, the work by Ali et al. (2017) offers many insights applied to the medical scenario also highlighting the pervasive nature of security. However, this requires to engineer privacy and security techniques able to scale from a datacenter dimension to the single user device. Unfortunately, full scalability properties are difficult to achieve and pose different challenges, for instance excessive resource requirements or energy drains (Caviglione et al., 2017).

As envisioned in the work by Coccoli et al. (2017), one of the ultimate goals of a smarter university is the deployment of ICT solutions to let individuals collaborate and cooperate. By using technologies *à la* Industry 4.0, universities can manage assets and resources (Coccoli et al., 2016), develop proper access information, and design safer campuses and buildings (Aldowah et al., 2017). At the same time, this causes additional vulnerabilities, as the entire university becomes part of the smart city.

Concerning mobile and ubiquitous learning approaches, their adoption in a smart city scheme could expose devices of users (e.g., smartphones and tablets) to many attacks, including data exfiltration of biometric information or geo-tagged data, colluding applications and energy draining attacks, DoS, zombification and cycle stealing threats, for instance for mining crypto currencies (Cabaj et al., 2018).

As a concluding remark, the plethora of IoT nodes, smart devices, home appliances and wireless sensors potentially account for a "security tsunami" (Dragoni et al., 2016). Indeed, this heavily impacts on the technological infrastructure (as discussed in Section 5), but also shifts part of the responsibility on students and teachers. Therefore, training and technological awareness of individuals should be considered a prime countermeasure.

4. Data Space

The data space ***D*** is where information relevant to the learning activities circulate. In general, accounts and achievements of users are managed by the LMS, while learning objects, learning analytics and interactions among students have not clear boundaries. For instance, measurements coming from sensors network as well as open data published by the municipalities can be mixed in a smart city. Therefore, data should support standard formats for both store and exchange purposes. This allows accessing a vast scientific literature and software libraries, while reducing vulnerabilities caused by poor design or implementations. For instance, the work by Bartoli et al. (2011) reviews the different actors that concur for the security of a "smart" scenario: the resulting technological space is very mixed and requires a meticulous management. The work of Gharaibeh et al. (2017) offers a holistic view of the lifecycle of data within a smart city. In more detail, authors observe that interconnected objects demand for security and network technologies able to handle data collection, processing and dissemination. This poses several cross-layer challenges and their negligence may have catastrophic outcomes. In fact, overlaying a learning application on a smart city worsens the resulting data space, which can be also cross-pollinated with bits of information gathered from sources linked with the account of the learner. As a consequence, leakage of data or functionalities belonging to the learning application should not impact on the city or partially void the physical security of citizens and users. In this vein, a major risk deals with de-anonymization attacks and vulnerabilities of users at a physical level. Multiple profile fusion attacks can be done in social media, and gathered data can be used to empower social engineering threats. Attackers posing as a learner or as a teacher can manipulate the data from the smart city or leak sensitive information such as the physical location of hands-on laboratories, or preferred smart devices used to perform assignments.

Another relevant risk concerns data, which could be vast and contain composite and untrusted information coming from sensors, devices and crowds. Specifically, it can be used to hide communication channels, which can be used to exfiltrate sensitive bits (e.g., identity of learners or their credentials), or to perform profiling campaigns, to transform portions of the software architecture in elements of a botnet (Wendzel et al., 2014).

Concerning multimedia data, a variety of IoT nodes and smart devices exploit video information to automatically recognize patterns, objects, or shapes. Usually, this is done to enforce security or to perform some optimizations, for instance by counting people or vehicles using a portion of the street. Indeed, video is also important for learning purposes and it is a valuable tool to quantify the attention of the learner as well as to adapt the material or re-think some learning strategies (Farhan et al., 2018). The collected information has to be properly secured and anonymized as it can leak many privacy bits, as well as it can be exploited for different attacks, including to feed machine learning algorithms to produce fake identities or fraudulent photomontages.

As regards possible pollinations with other applications interacting with IoT or wearable sensors, smart e-learning frameworks share many concerns and pitfalls with the e-health universe. Specifically, it is very hard to develop a platform able to exercise suitable control on the entire “information chain” and security and privacy requirements should be properly standardized, especially to enforce a privacy and security by design approach (Guadagni et al., 2015).

Lastly, when in the presence of a balkanized space like the one characterizing smart city used for learning purposes notions dealing with cybersecurity should be precisely clarified. For instance, Heath (2014) indicates that privacy is an ill-defined concept subject to different interpretations causing misbehaviors due to incompatible software implementations or unclear settings.

5. Infrastructure Space

The interactions within the infrastructure space ***I*** vary according to the specific learning needs. A major driver is the LMS, and its evolution from a closed system to a more distributed form heavily influences the security models to be adopted. In fact, legacy LMSs used walled-garden architectures, which handled the mere delivery of learning material. In this case, learners access the platform via web-based clients retrieving data through secured Internet connections or intranet accesses. In contrast, today many activities involve entities and systems outside the platform and may rely on very different technological solutions. In this perspective, the most significant is cloud/fog computing, which is crucial to develop future e-learning applications, since it is fundamental to implement sensor fusion in a fully connected city (Schaffers et al., 2011).

Cloud and fog computing approaches to support e-learning applications, including learning analytics services, are becoming ubiquitous and populate the toolbox of many course architects and software developers (Manca et al., 2016; Fernández et al., 2014; Caviglione et al., 2011a). Therefore, Education-as-a-Service or Smart-City-as-a-Service will become relevant paradigms in the next future, thus requiring proper security levels, including enforcing privacy of users and protection of information, typically spread over different nations with different laws and requirements.

The e-learning community should also focus on cloud security to borrow pros and evaluate cons. For instance, Jeong et al. (2013) underline the need of developing suitable techniques to encrypt the learning context of students and to retain backup data. This accounts for ad-hoc security policies, and mechanisms to enforce data preservation, service availability, reliability, and resiliency. Fortunately, such properties are often built-in and can be shifted from the e-learning framework towards the cloud via proper delegation schemes. At the same time, this could lead to additional vulnerabilities caused by unsecure network connections or Man-in-the-Middle (MitM) attacks. Security and privacy concerns of the joint use of cloud and e-learning are also relevant among students (Arpaci et al., 2015), thus the introduction of the smart city factor may lead to their exacerbation and should be planned carefully.

6. Examples

In this section, we present three toy examples describing how the proposed holistic model can be used to drive the evaluation of security and privacy risks of a learning applications interacting with the smart city. We underline that our approach allows rating the overall learning framework to have a guideline for its deployment.

6.1 Example: Real vs Synthetic Data

Let us consider an application enriching the learning experience with data from the field. To this aim, two possible paradigms can be used (Caviglione & Coccoli, 2018): *i*) the information is made available in an asynchronous manner, for instance by the municipality via open data, or *ii*) data is collected "live" with ad-hoc devices, such as, sensors and IoT nodes.

For the case *i*), risks are primarily limited to the data space ***D***. For instance, data can be altered with fake information (d_1='data corruption'), contain hidden information (d_2='steganography attack') or be not properly anonymized thus including sensitive data (d_3='privacy leak'). Obtaining open data usually requires downloading some files from a host operated by the municipality, hence MitM attacks targeting the ***I*** space are not likely. Instead the learner can be attacked in his/her space ***L*** by using corrupted data to alter the behavior of the host (e.g., by exploiting a l_1='buffer overflow'). Merging the two spaces can increase the number of vulnerabilities, hence making the space ***C*** less secure. For instance, if the learning application implements a hands-on laboratory, the physical security of the user can be endangered by poisoning ***D***, i.e., by exploiting d_1='data corruption', and ask the user to move in an unsafe physical space location. This corresponds to a new l_2 ='physical security' threat. As a result, J=2+3=5, instead of the original J=4.

Instead, for the case *ii*), additional attacks can happen in ***I***, which is a relevant part of the overall learning experience. In fact, data can still be corrupted or manipulated as in the previous case, but also spoofed or reduced by making a sensor unreachable, i.e., i_1='spoofing', or the user can be deceived by injecting fake GPS data, hence leading to i_2='GPS manipulation'. Therefore, the overall space ***C*** can be further augmented with joint threats like, d_2+i_1 in which data is manipulated to exfiltrate information through a covert channel (l_3='exfiltration of data'), or l_1+i_1 leading to DoS by means of ad-hoc crafted packets generated via IoT nodes. Nevertheless, physical space can be also endangered as in the previous case by using "live" data instead of static entries in the file. As a result, J =(2+3+ 2)+2=9. The course architect can then use this indicator to evaluate if his/her team, the budget, or the skills of the teacher/learners are adequate with respect to the resulting complete space ***C***.

6.2 Example: Virtualized Environments

In this example, we consider a learning application based on the Platform-as-a-Service paradigm. As described by Coccoli et al. (2015), students from different universities interact with remote virtual machines to complete assessments or to emulate a laboratory or hardware facilities not available locally. Let us focus on the infrastructure space ***I***. In general, for the case of cloud, it is partially outside the control of the developer of the learning experience. As a consequence, virtual machines can collude to exfiltrate data via a local covert channel or exploit shared portion of the hypervisor or of the underlying hardware to exchange information (Cabaj et al., 2018). This leads to a vulnerability i_1='unintended exchange of data' and it is limited to the PaaS provider. Let us now also consider the data space ***D***. A possible implementation of the learning experience can use a mixed public/private cloud scenario, where personal information of learners is locally stored. Another idea could rely upon a fully public framework. However, information is stored in the cloud and can be exfiltrated by using the vulnerability i_1. For instance, information to be processed by learning analytics algorithms or data to perform authentication and accounting may reside in a virtual machine and can be leaked towards another one under the control of the attacker. Accordingly, this may lead to a d_1=leak of sensitive data or login credentials. As a result, ***C*** is characterized by J=2, whereas the mixed public/private solution by J=1. Hence, a sort of trade-off among fine-grained control of data, complexity and cost of the platform has been made. space ***C***.

6.3 Example: Contactless Data

Another possible example of the interplay among different technologies considers the interaction of annotated objects (Coccoli & Torre, 2014), which are often accessed via RFID, for instance in cultural heritage applications or in smart museums (Caviglione et al., 2011b). In this case, the museum has to be considered a portion of the smart city, and similar usage paradigms can be envisaged in other scenarios, e.g., when the Near Field Communication (NFC) technologies are deployed. By considering our modelling, the usage of contactless communications may cause additional fragilities in the ***I*** space, as the data can be intercepted via a MitM attack, i_1='MitM'. This can be mixed with the vulnerabilities in the data space, for instance d_1='plain data', which happens when the information is not properly encrypted. Such a case characterizes LMS not supporting end-to-end cyphering of flows, or developers not considering as sensitive some bits of information. Hence, d_1 can be mixed with privacy leaks of the learning space $\boldsymbol{L}$ (such as l_1='learning objects enriched with personal information') and the attacker can exploit $i_1+d_1+l_1$ to perform a user profiling by means of a fusion of all the data sensed, including information on "when" and "where" it has been collected. As a consequence, J=(1+1+1)+1=4, thus: course developers should understand the security requirements of data, limit the amount of unneeded information exchanged, and avoid to allow personal details to travel through the smart learning infrastructure.

7. Conclusions and future work

In this paper, we have introduced a holistic model to identify and classify threats and vulnerabilities characterizing e-learning frameworks taking advantage of smart cities. As shown, the resulting space is very complex and the combination of a multifaceted set of technologies multiplies the risks impacting over the entire architecture.

The issues presented for each space, as well as toy examples, demonstrated that emerging paradigms and applications require to not neglect the complex interplay between security and privacy requirements. This is especially true for the case of smart cities, since it is composed of entities like buildings, which are very attractive targets for cybercriminals. Therefore, the e-learning applications should be hardened as to not represent an entry point for the attack or to not behave as a trojan. Besides, the impact of IoT is cross-space, i.e., it affects all the functional layers. Learners and teachers should be also educated in the risks and fragilities arising from the use of information coming from realistic setups or when interacting with software artifacts beyond the control of the course architect. Future work aims at refining the model, possibly by using formal methods. A relevant part of our research deals with the development of suitable algorithms to automate the detection of privacy leaks and security hazards during the design phase of a smart-capable course.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 11-22

Technology Integration in Education: Source of Intrinsic Motivation, Self-Efficacy and Performance

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(submitted: 26/11/2019; accepted: 17/03/2020; published: 30/04/2020)

Abstract

The research study is designed to investigate the effectiveness of a blended learning program through experimental setup, where 82 (45control sample and 37 experimental sample) students participated in the research activity. The researcher designed and applied blended learning program to enhance students' motivation towards achievements in the syllabus of O-levels Chemistry subject. Hypothesis testing achieved through regression analysis, Split Plot ANOVA, independent sample t-test and Bootstrapping for mediation. Results suggest significant and positive relationship between blended learning program, intrinsic motivation, self-efficacy, and academic achievements. Furthermore, female participants were found to be more motivated in comparison with male participants. The researcher has further discussed possible reasons for insignificant relationships among variables. It is recommended to apply training to pupils before engaging students in online learning programs. In addition, in future course of study longitudinal research design with large sample size should be adopted to develop more valid and reliable normative instruments for South Asian context.

KEYWORDS: Blended Learning, Chemistry, Self-Efficacy, Intrinsic Motivation, Grade Motivation

DOI
https://doi.org/10.20368/1971-8829/1135188

CITE AS
Siddiqui S., Thomas M., Nazar N., (2020),Technology Integration in Education: Source of Intrinsic Motivation, Self-Efficacy and Performance.Journal of E-Learning and Knowledge Society, 16(1), 11-22. https://doi.org/10.20368/1971-8829/1135188

1. Introduction

Science education is among the most important subjects taught in school and its importance are mainly due to its application in solution of real-world problems as well as its relevance to students' lives in enhancing their critical thinking skills. Among the branches of science, Chemistry is the one that is found everywhere, every time in our surroundings and it interrelated with other branches of sciences as well. Students' discouragement towards learning chemistry is visible and highlighted by many researchers because of the study of plentiful amount of hypothetical concepts, those requires substantial effort and time commitments from the students (Akram, Ijaz & Ikram, 2017; Salta & Koulougliotis, 2015; Sharaabi, Kesner & Shwartz, 2014; Sirhan, 2007). Furthermore, students' perception and confidence to score well in this subject usually decreases over time, as the complexity level increases, especially when subject provides less information about the importance and/or usefulness of the chemistry course (Aregawi & Meressa, 2017). Wu and Foos (2010) reported that most of the learners studying chemistry were not interested and motivated to pursue a career in chemistry. Students usually opt these courses to fulfill the requirement of a degree in fields of their interests such as medical or engineering. This lack of motivation is alarming as chemistry is the most important subject connecting all the sciences together. Furthermore, the field of chemistry, science, and technology have an impact on the economic heart of every industrialized, and technologically progressive society (Burmeister, 2012).

The researcher of the current study designed and experiment blended learning approach to influence students in terms of motivation and interest to learn chemistry. Keshta and Harb (2013) defined blended

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learning as "a natural evolution of e-learning towards a complete program of various multimedia applied in an ideal way to solve problems, taking care of the individual differences and achieving distinguished teaching". Though blended learning is challenging (Kihoza et al., 2016; Florian & Zimmerman, 2015), it has positively influenced students motivation and shown positive results (Zainuddin & Perera, 2019; Edward, Asirvatham & Johar, 2018).

Deci and Ryan (2000) presented self-determination theory and explained that that pupils are naturally active and engaged, if their motivation level is high. Within self-determination theory, intrinsic motivation keeps people engaged in learning, knowledge gain exercises without any greed of reward or fear of punishment. Taylor and colleagues (2014) studied self-determination theory and connected relation of motivation to academic achievements in a cross-cultural study between Canadian and Swedish students and found robust results. Ferrell, Phillips, and Barbera (2016) studied self-efficacy, interest and effort beliefs as a course of motivation among 170 chemistry students and found that self-efficacy was the strongest influencer for academic achievement. Similarly, Husain (2014) research on 135 Pakistani business students in Karachi in 2012-2013 found a significant positive relationship between self-efficacy and academic motivation.

Thus, in this study, the researcher has applied blended learning approach to the students of grade IX, chemistry, in order to facilitate them and to provoke their motivation in terms of self-determination, intrinsic motivation, self-efficacy, career motivation and grade motivation towards better academic scores.

It has been tried to explore the use of blended learning with the help of EDMODO portal, to create ambiance and to create self-determined, intrinsic, career and grade motivated students with higher level of self-efficacy, ready to learn and explore world of chemistry and show their potential towards scientific progress of the country. In this study, a quantitative approach has adopted for computation of variables with the aim to establish connections between trends and research variables. Regression Analysis, independent sample t-test, Split-Plot ANOVA, Mediation through bootstrapping used for analysis and interpretations using SPSS version 20 and smart PLS version 3.

Researches based on application of motivational strategies to learn chemistry is usually found with university level students (Ferrell, Phillips & Barbera, 2016; Rosenzweig & Wigfield, 2016) but limited research with school level students are seen. Similarly, blended learning or use of Learning Management Systems has penetrated effectively in tertiary level of studies (Wiyarsi, 2017; Sun et al., 2017; Waheed et al., 2016), however its application with secondary classes, especially in the field of chemistry, is yet to be explored. Therefore, the researcher designed this computer-assisted instructional program at the secondary level of school for students to enhance their motivation towards achievements in O-levels Chemistry, to make this study unique and novel especially in the South Asian region.

2. Literature Review

Below is a review of the literature identified applications, limitations, challenges and influences of blended learning program at various levels of education in different regions.

Lee, Lau, and Yip (2016) studied the impact of the use of the Moodle learning management system on students of three tertiary level universities in Hong Kong, and demonstrated positive outcomes for qualities such as keenness, understanding of concepts and self-assurance in learning science. Similarly, studies conducted in Pakistan by Waheed and colleagues (2016) found that blended learning has a positive impact on motivation. In continuation, a study conducted by Hashemyolia et al. (2014) established a strong relationship between Learning Management System, and enhanced self-regulated learning strategies and improved performance. Use of multimedia in educating science and its impact on academic achievement and attitude of 60 students of Grade 8 in Karachi, highlighted by Shah and Khan in 2015. Findings showed that students taught through multimedia produced higher scores as compared to students learned through traditional teaching method.

Boiché and colleagues (2008) inspected and compared the impact of the level of self-determination among 215 participants in 10 weeks gymnastic class and found students with higher level of self-determination had shown higher capability to achieve higher grades.

Lin-Siegler, Dweck, and Cohen (2016) pointed out the fact that students' motivation, can be influenced by many factors such as extrinsic incentives, personal beliefs, personal goals and interests. Thus, working with students' beliefs' can potentially enhance students' academic motivation and performance. Similarly, Dev (1997) in her review article explored that those with higher academic intrinsic motivation function effectively than children with poor motivation. In continuation, Ferrell, Phillips, and Barbera (2016) in their research design highlighted motivational precursors required to study chemistry. The researcher studied self-efficacy, interest and effort beliefs as predictors of motivation among 170 chemistry students. Multiple regression and path analysis explored that self-efficacy was the strongest variable towards better grades.

Salta and Koulougliotis (2015) evaluated motivation and the interest of students regarding learning chemistry at Athens during 2012-2013. Sample comprised of 163 boys and167 girls from secondary school. Results showed that male students' self-determination was lower than female participants while age comparison revealed that lower grade students had a higher motivation than secondary students.

Husain (2014) conducted a research on 135 Pakistani business students in Karachi in 2012-2013 to highlight relationship between self-efficacy and academic motivation. Pearson Product Moment Correlation test showed significant and positive relationship between self-efficacy and academic motivation, however, t-test showed no gender differences in the motivation of the participants.

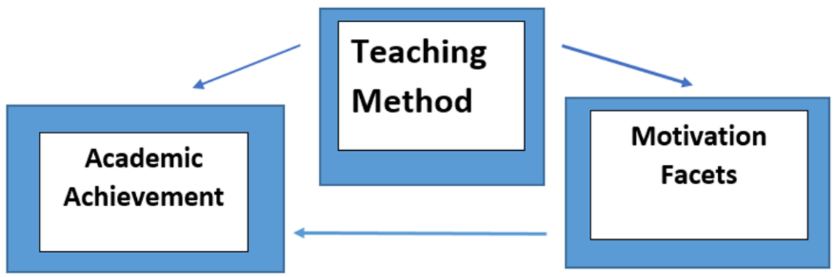

Figure 1 - Impact of Blended learning on Motivation and Achievement.
Source: Developed by Author

3. Research Methodology

Researcher in the current study has adopted a quantitative research pattern aligned with the quasi-experimental and pre-post experimental design, which aimed to examine, direct and indirect influence of the blended learning program on motivational indicators (Figure 1). The researcher has used a blended approach to develop skills regarding comprehension and calculations, required to get expertise with Cambridge O-Levels Chemistry syllabi. Purposive sample design has been adopted due to the accessibility of the researcher to chemistry students as a teacher in a well-known convent school at Karachi. It is supported by the literature that the complexity of the content (Tilahun & Tirfu, 2016; Zusho, Pintrich, & Coppola, 2003) has an influence on the motivation of the students. To maintain the uniformity of the content, similar syllabus was taught and tested, based on the topics of Particulate model of matter, Laboratory practices and Separation Techniques. The researcher invited student on EDMODO portal by emails. Experimental Group consisted of 37 (23 boys and 14 girls) students, started participating in activities on the online program; however, 45 (15 boys and 30 girls) students did not join the portal and preferred studying in regular classes and became the part of the control group. The students in both groups were similar in their general achievement and were studying chemistry as a separate subject for the very first time, in the first term of the scholastic year (2018-2019).

3.1 Activities in Blended and Traditional Classroom

Students from both groups studied via traditional lecture method; however, experimental group students also participated in online activities. Virtual learning classes were conducted using EDMODO portal. Demographic information of the experimental group showed that the most common activity that students engaged in during the blended learning environment were attempts to practice quizzes at the end of each topic. Some of the other common activities included responding to academic-related messages from teacher and fellows, watching videos posted by the teacher, personal inquiry-based messages to the instructor, participation on poll questions and discussion forums. The researcher tried to make students self-efficient and grade motivated by involving students in online quizzes and discussions and through providing them feedback along with the comments and achievement badges for active learners and performers. These cheering badges are built in by default and available on EDMODO's online portal. To create students' career-based motivation, the researcher recordings and media connecting content's application with real life situations. Similarly, postings and poll questions by the royal society of chemistry were replicated in online classes to create awareness chemistry as a subject application and its importance. This research experiment continued for 10 weeks from August 2018 till October 2018.

3.2 Research Variables

The study comprised of the following variables:

A- The independent variables represented in the teaching program:
1. Blended learning program
2. Traditional method

B- The dependent variable represented in:
1. Motivation to learn Chemistry
2. Achievements in Standardized Test

3.3 Research Instruments

1. *Chemistry Motivation Questionnaire*: This is modified form of Self-Reported Science Motivation Questionnaire developed by Glynn, (2011). This scale based on 22 questions with 5-point Likert scale (0= Never, 1= Rarely, 2= Sometimes, 3=Often, 4=Always) to measure students' motivation to learn chemistry at the end of the research program.
2. *Achievement Test*: This test was designed by the researcher to check and compare the academic achievements of both groups. This test was based on 20 multiple choice questions, and 20 marks open-ended questions. These questions were designed by the researcher from syllabus taught by tradition and blended learning methods, to check, understanding, memorization, concepts and analytical skills of students.
3. *Pre-test*: This test was based on 10 objective based questions with 10 marks, but marks were then converted to 40 for analysis purpose and to maintain similarity with post standard test. Participants from both groups appeared for pre-test at the start of the experimental program.

4. Data Analysis and Results

Before testing hypothesis, and establishing relationships among the variables, researcher run factor analysis to ensure reliability and validity of the tool used.

4.1 Kaiser–Meyer–Olkin (KMO) and Bartlett's tests

The results shown in Table 1 is representing that the items within each factor are adequate for factor analysis (Kaiser, 1974) and matrix is not identity and factor analysis is possible (Table 1) (Bartlett, 1950). Average variance extracted is 59 % which is making it fit for further factor analysis.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin	Measure of Sampling Adequacy.	.708
	Approx. Chi-Square	924.643
Bartlett's Test of Sphericity	Df	300
	Sig.	.000

Table 1 - KMO and Bartlett's Test.

4.2 Factor Analysis

Final factor structure designed by using PLS version 3 (Table 2) for the Chemistry Motivation Questionnaire comprised of

- *Factor 1*: Intrinsic Motivation - 4 items
- *Factor 2*: Self Determination - 5items
- *Factor 3*: Self Efficacy - 5 items
- *Factor 4*: Career Motivation - 5 items
- *Factor 5*: Grade Motivation - 3 items

Operational definitions of the variables are:

Self Determination: self-determination has been defined as "the ability to identify and achieve goals based on a foundation of knowledge and valuing oneself" (Field, Hoffman & Cornell, 2016).

Intrinsic Motivation: it is like an autonomous behaviour, performed with a full sense of inclination towards completion of the task (Ryan and Deci, 2000)

Self-Efficacy: Albert Bandura (1982) defines it as a personal judgment of "how well one can execute courses of action required to deal with prospective situations".

Career Motivation: author defined career motivation as an extrinsic motivation representing achievement in career objectives and goals.

Grade Motivation: author defined grade motivation as a kind of extrinsic motivation to achieve better credentials and accomplishments in the form of better scores.

Item	Intrinsic Motivation	Self Determination	Self-Efficacy	Career Motivation	Grade Motivation
Intrinsic Motivation 1	0.802				
Intrinsic Motivation 2	0.739				
Intrinsic Motivation 3	0.767				
Intrinsic Motivation 4	0.847				
Self Determination 1		0.686			
Self Determination 2		0.726			
Self Determination 3		0.766			
Self Determination 4		0.732			
Self Determination 5		0.690			
Self Efficacy 1			0.783		
Self Efficacy 2			0.539		
Self Efficacy 3			0.665		
Self Efficacy 4			0.623		
Self Efficacy 5			0.666		
Career Motivation 1				0.872	
Career Motivation 2				0.875	
Career Motivation 3				0.781	
Career Motivation 4				0.416	
Career Motivation 5				0.511	
Grade Motivation 1					0.407
Grade Motivation 2					0.796
Grade Motivation 3					0.796

Table 2 - Factor Analysis.

Reliabilities	No. Of Items	Cronbach's Alpha (From PLS)	Composite Reliability
Intrinsic Motivation	4	0.798	0.869
Career Motivation	5	0.884	0.831
Self Efficacy	5	0.685	0.792
Self Determination	5	0.790	0.844
Grade Motivation	3	0.527	0.718

Table 3 - Reliability of the Instrument.

	Career Motivation	Grade Motivation	Intrinsic Motivation	Self Determination	Self -Efficacy
Career Motivation					
Grade Motivation	0.346				
Intrinsic Motivation	0.391	0.314			
Self Determination	0.354	0.542	0.608		
Self-Efficacy	0.340	0.541	0.777	0.693	

Table 4 - Heterotrait-Monotrait ratio of correlations (HTMT).

4.3 Reliability of the Instrument

Data reliability is measured through Cronbach's alpha using smart PLS version 3. In the reliability test, the value of Cronbach's alpha should be greater than 0.5 (Cronbach, 1951) (Table 3).

4.4 Construct Validity

Tseng et al., (2006) suggested that value of composite reliability greater than 0.6 confirms convergent validity of the instrument (Table 3).

Heterotrait-Monotrait ratio of correlations **(**HTMT) are used to check discriminant validity. Henseler, Ringle and Sarstedt (2015) explained that if the HTMT value is below 0.90, discriminant validity is established (Table 4).

4.5 Split-Plot ANOVA

Split-plot ANOVA is a statistical test, used to identify differences between control and experimental groups' achievements, before and after different teaching strategies applied for a fixed duration of time. It is usually represented with a graph (refer to Figure 2).

The plot of the means (shown on vertical axis) across pre-post academic achievements (shown on horizontal axis) shows evidence the results on the experimental group being higher than those on the control sample. Thus, it shows a significant improvement in students' performance in terms of academic credentials and concepts building with the experimental group participants as compared to control group. To further investigate this relationship, independent sample t-test is applied in later part of analysis.

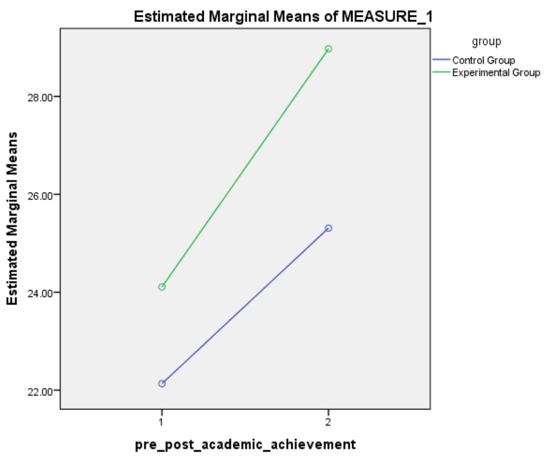

Figure 2 - Pre-test and Posttest Academic Achievement. Source: Developed by Authors

4.6 Independent sample t-test

Independent Sample t-test is used to define means comparison between 2 groups. If the value of significance is greater than 0.05, means are considered equal (Keselman, Othman, Wilcox, & Fradette, 2004). Levene's test of equality indicated that in all relations equal variances were found. In this study, teaching method has shown no significant relationship with career motivation, grade motivation, and self-determination. However, a significant difference between two groups in terms of intrinsic motivation, self-efficacy, and academic achievement are evident (Table 5).

4.7 Regression Analysis

Regression Analysis was run to establish impact of motivational factors on academic achievements. The model used to determine impact of motivational facets on academic achievement is:

Academic Achievement= α +β1 (intrinsic motivation) + β2 (Self Efficacy) + β3 (Self Determination) +β4 (Career Motivation) + β5 (Grade Motivation) + error

A significant relationship is established between intrinsic motivation and academic achievement where significant values are lower than 0.05 (Table 6). The

	Groups	N	Mean	Std. Deviation	Mean Difference	t-value	df	Sig, (2-tailed)
Self-Efficacy	Control	45	3.6489	.65249	-0.44300	-3.003	80	0.004
	Experimental	37	4.0919	.67921				
Intrinsic Motivation	Control	45	3.0389	.87249	-0.52868	-2.597	80	0.011
	Experimental	37	3.5676	.96941				
Career Motivation	Control	45	2.9600	1.33253	-0.16973	-0.625	80	0.534
	Experimental	37	3.1297	1.07416				
Self Determination	Control	45	3.4844	.75014	-0.25069	-1.393	80	0.167
	Experimental	37	3.7351	.87946				
Grade Motivation	Control	45	4.4222	.67570	0.16096	1.063	80	0.291
	Experimental	37	4.2613	.69003				
Academic Achievement	Control	45	25.3111	5.20412	-3.66186	-3.040	80	0.003
	Experimental	37	28.9730	5.68862				

Table 5 - Independent sample t-test, Probability $\leq$ 5%.

Model	B	t	Sig.	Collinearity Statistics Tolerance	VIF	R	R Square	Adjusted R Square
(Constant)	24.735	4.997	.000					
Intrinsic_Motivation	2.135	2.522	.014	.585	1.710			
Self_Efficacy	.130	.113	.910	.591	1.692			
Self_Determination	-.534	-.564	.575	.634	1.578	.340[a]	.116	.058
Career_Motivation	.055	.101	.920	.864	1.158			
Grade_Motivation	-.808	-.842	.402	.880	1.136			

Table 6 - Regression Analysis, Dependent variable: Academic Achievement. Probability $\leq$ 5%

	Gender	N	Mean	Std. Deviation	Mean Difference	T	Df	Sig. (2-tailed)
Academic Achievements	Male	38	27.5000	6.21137				
	Female	44	26.5000	5.24072	1.00000	.791	80	.431
Intrinsic_Motivation	Male	38	3.3882	.99271				
	Female	44	3.1818	.91079	.20634	.981	80	.329
Self_Efficacy	Male	38	4.0053	.67781				
	Female	44	3.7136	.69201	.29163	1.921	80	.058
Self_Determination	Male	38	3.4632	.86381				
	Female	44	3.7136	.76237	-.25048	-1.395	80	.167
Career_Motivation	Male	38	2.9632	1.11098				
	Female	44	3.1000	1.31361	-.13684	-.505	80	.615
Grade_Motivation	Male	38	4.1667	.75834				
	Female	44	4.5076	.57281	-.34091	-2.315	80	.023

Table 7 - Independent Sample t-test (Gender Differences). Probability $\leq$ 5%

	Original Sample	Sample Mean	Standard Deviation	T-value	P-values
Intrinsic Motivation → Academic Achievement	0.253	0.266	0.105	2.422	0.015
Teaching Method →Academic Achievement	0.254	0.249	0.118	2.142	0.032
Teaching Method →Intrinsic Motivation	0.274	0.288	0.104	2.642	0.008

Table 8 - Path Coefficients.

	Original Sample	Sample Mean	Standard Deviation	T-value	P-values
Intrinsic Motivation → Academic Achievement					
Teaching Method →Academic Achievement	0.069	0.076	0.042	1.648	0.099
Teaching Method →Intrinsic Motivation					

Table 9: Indirect Effects.

	Original Sample	Sample Mean	Standard Deviation	T-value	P-values
Intrinsic Motivation → Academic Achievement	0.253	0.266	0.105	2.422	0.015
Teaching Method →Academic Achievement	0.322	0.325	0.108	2.972	0.003
Teaching Method →Intrinsic Motivation	0.274	0.288	0.104	2.642	0.008

Table 10 - Total Effects.

coefficient of intrinsic motivation is 2.135 and is significant which shows that 1 degree increase in intrinsic motivation results in 2.15 degree rise in academic achievement. To check mediating effect of intrinsic motivation bootstrapping technique is used using PLS-version 3.

4.8 Multicollinearity

Multicollinearity is calculated through variation inflation factor, where it is suggested that VIF of 5 or lower (i.e., Tolerance level of 0.2 or higher) is robust to avoid multicollinearity issue (Hair et al., 2006) (Table 6).

4.9 R-square value

The R-squared, (also called the coefficient of determination) determines strength of a relationship and model fitness and it is used to predict chances of error. In Social Sciences low R square values are often expected (Neter et al, 1996). However, according to Cohen (1992) R-square values more than 0.1 are acceptable that shows small to medium effect size (Table 6).

4.10 Gender Differences

Independent sample t-test showed no differences among females and males in terms of self-efficacy, intrinsic motivation, career motivation, self-determination and academic achievements (Table 7). On the contrary, a significant difference is observed among different genders in terms of grade motivation. It is concluded from the mean values that grade motivation or thrust to achieve better grades is higher or profound among the female participants.

4.11 Mediating Effect of Teaching Methods on Academic Achievement through mediation of Intrinsic Motivation

Bootstrapping for 5000 sample size was run and Table 8 is formulated for path coefficients. Robins and Greenland (1992) explained direct and indirect effect as in Figure 3. The product of path coefficients "A" and "B" is termed indirect, however, coefficient "C" is used to highlight the direct effect of the research model. The total effect is defined as the addition of the direct and indirect effects (C' + AB in the model).

Path coefficients have indicated that intrinsic motivation has an impact on academic achievement (p-value <0.05). Similarly, the teaching method has also influenced on intrinsic motivation as p-values are less than 0.05. But, intrinsic motivation impact as a mediator on academic achievement is not established as p-value is > 0.05 (Table 9 and Table 10).

5. Discussion and Suggestions

Aligned with the studies conducted by Zainuddin and Perera (2019); Edward, Asirvatham and Johar (2018); Ain, Kaur and Waheed (2016), Tang and Chaw (2016), Cheng and Chau (2016), Gambrari, Yusuf and Thomas (2015) and research conducted by Waheed et al. (2016) in Pakistan, findings of the current study have revealed that the use of LMS has a significant influence on improved performance and academic achievements. Thus, as highlighted by Shah and Khan (2015); Iqbal and Bhatti (2017); Vasileva-Stojanovska et al. (2015), technology integration in education setup results in improved performance and better academic achievements. However, as pointed out by Wiyarsi (2017) continuous training guidelines are needed regularly for further development of teachers'

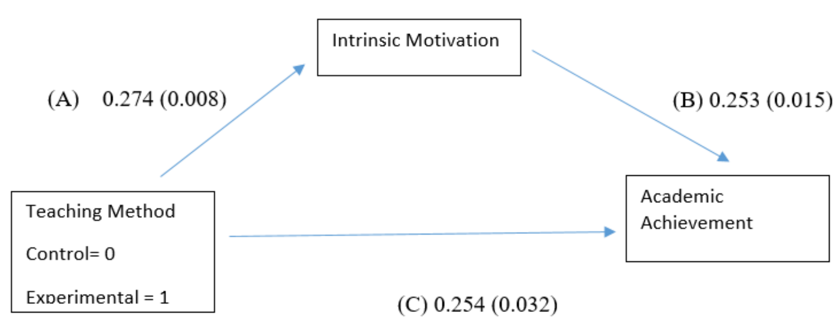

Figure 3 - Model 2, Mediating Effect of Intrinsic Motivation on Academic Achievement.
Source: Constructed by the Author(s)

competencies and abilities for improved resource management and successful execution of technology-oriented classroom lessons.

In succession with the conclusions of Ho et al. (2016), current study represented that use of the blended learning program has a positive impact on self-efficacy of the students. Literature has supported the fact that improved self-efficacy results in increasing willingness to put efforts from students' side to deal with the situation. However, in continuation of the study conducted by Baanu, Oyelekan, and Olorundare (2018) and in contrast with the study of Ferrell, Phillips and Barbera (2016) and Husain (2014) improved self-efficacy has not shown any significant impact on academic achievement. Thus, as highlighted by Baanu, Oyelekan, and Olorundare (2018), it is recommended that self-efficacy alone cannot predict performance and should be accompanied by other motivational factors for robust results.

In continuance of the research conducted by Waheed et al. (2016); Noour and Hubbard (2014), computer-based learning has found a significant relationship with intrinsic motivation in the current study. Furthermore, as highlighted by Deci and Ryan (2000); Yousaf, Yang and Sanders (2015), the current study has proven that intrinsic motivation is acting as strongest herald towards better academic achievements. Use of blended learning approach to enhance career motivation, grade motivation, and self-determination has found insignificant in the current study and as highlighted by Rosenzweig and Wigfield (2016), it is suggested that variables should be aligned with motivational theories for successful interventions and educational policies and systematic reviews of strategies should be achieved vigorously before applying these into new contexts.

Persistent with the results of Husain (2014); Wang, Degol and Ye (2015), and in distinction to the results of Salta and Koulougliotis (2015); Glynn et al. (2011); Guo et al. (2015) no significant difference was found in intrinsic motivation, self-efficacy, self-determination and career motivation. However, a significant difference in grade motivation among male and female students recognized, which has opened a new dimension of research to find why females' grade motivation is higher than male participants. It is recommended to further explore reasons behind these differences.

To overcome limitations of blended learning as highlighted by Appana (2008), it is recommended to have training sessions to make students familiar with the environment and making them technology savvy, before applying the technology-based lessons and activities.

6. Recommendations for Future Research

The key limitation of the present study is small sample size with a shorter span of experimental duration which usually do not accurately capture the true assessment of measurement invariance over a longer period of time. Thus, it is suggested that the similar research should be replicated using longitudinal research design with modification of sample size and incorporating data from more institutions from different areas of Karachi or Pakistan. Furthermore, it is recommended to explore reasons for gender differences in terms of grade motivation, in order to highlight basic provocateurs responsible for such variations.

As highlighted by Nausheen (2016), it is recommended to develop new tools or translate already developed tools to measure motivational facets targeting larger population from the society, especially from underprivileged backgrounds where the Urdu language or Vernacular is used as the main medium of communication.

Tynan, Ryan and Mills (2015) emphasized the fact that international literature though focused on outcomes of blended learning but very limited literature is available on the increase workload of teachers due to e-learning or technology integration. Thus, it is recommended to explore more about the workload on teaching in e-learning programs especially in South Asian regions.

Acknowledgments

Thanks to Mahwish Siddiqui, for being constant support throughout this research study. Special thanks to Dr.Tehseen Jawaid, who facilitated the researcher to build her Quantitative Research Skills and to Mr. Nur Ali Tejani for his devotions and familiarizing computer instructional learning in a very motivating manner.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 23-32

Computer-assisted instruction, project based learning and achievement of Deaf learners in Biology

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(submitted: 28/11/2019; accepted: 13/04/2020; published: 30/04/2020)

Abstract

Deprivation of language abilities has negative influence on academic achievement of deaf learners especially in biology. Although, previous studies have underscored teaching approaches as a factor that influence participation and low achievement in biology but little or no studies exist to determine the effects of computer and project based learning approaches on the achievement of deaf learners in Biology. Therefore, this study determined the effect of computer-assisted instructions (CAI) and project based learning (PBL) on the achievement of deaf learners in Biology in Ibadan, Nigeria. The study engaged the pretest-posttest, control group quasi experimental research design. Purposive sampling technique was used to select deaf learners from three secondary schools in Ibadan, Nigeria. The participants were randomly assigned to two treatment groups: CAI, PBL and control group. Treatment lasted 8 weeks. Biology Achievement Test and Achievement Motivation Scale were used for data collection. Data were analysed using Analysis of covariance at 0.05 level of significance. Results showed a significant main effect of treatment of achievement in Biology among deaf learners ($F(2,28) = 11.432$, $\eta 2 = 0.574$). Participants exposed to CAI obtained the highest mean score of 13.74 followed by PBL group (10.51) and control group (9.15). There was also a 3-way interaction effect on deaf learners' achievement in biology. CAI was more effective in enhancing achievement in Biology among deaf learners the PBL. Therefore, Biology teachers to deaf learners should adopt CAI and perhaps PBL to motivate and stimulate deaf leaners' interest in life sciences.

KEYWORDS: Computer-assisted instruction, project based learning, deaf learners, biology, achievement in biology

DOI
https://doi.org/ 10.20368/1971-8829/1135190

CITE AS
Adigun O. T., (2020)Computer-assisted instruction, project based learning and achievement of Deaf learners in Biology.Journal of E-Learning and Knowledge Society, 16(1), 23-32. https://doi.org/ 10.20368/1971-8829/1135190

1. Introduction

Language deprivation and associated psycho-social factors can be identified as a factor that influences unequivocal science achievement of deaf learners when compared with their colleagues without hearing deficit. The poor performance of deaf learners in Biology and other science subjects in various examinations is worrisome to teachers, parents and other relevant stakeholders who are interested in the education of high school learners as a means to achieving the sustainable development goals. Yusuf and Afolabi (2010) and Umar, Fugu and Aliyu (2018) mention poor performance in Biology among high school learners, with no report of performance of deaf learners. However, it may be assumed that achievement in Biology among deaf learners will be lower than their hearing counterparts largely because deaf learners experience communication difficulties and lack access to incidental learning about nature and natural resources, ecosystem, human development and dynamics which are often presented verbally in classroom. Hence, due to teaching strategies which do not take cognizance of communication difficulties, deaf learners seem to have less interest in actively participating in scientific instructions. Thus, deaf learners are disconnected from life science subjects with elevated impaired self-efficacy and less motivation to studying life sciences.

Although it is expected that teachers of deaf learners and sign language interpreters should fill the gap in students' knowledge and use appropriate signs to pass on scientific instructions in the classroom. However, informal observation and discussions with science teachers in deaf schools in Nigeria revealed that such effort is yet to yield the desired results. Flores and Rumjanek (2015) aver that science teachers and interpreters in deaf schools find it difficult to express some biological concepts in other science-related subjects effectively using sign languages because they lack the required skills to effectively explain concepts to the students; hence, the performance of deaf learners in Biology may not be encouraging. Ugwuadu (2017) discuss the achievement of learners who sat for the Senior School Certificate Examination in Biology between 2012 and 2017. Similarly, Aidoo, Boateng, Kissi and Ofori (2016) note that there has been a significant trend in South Africa students' failure in physical sciences in the National Senior Certificate (NSC) final examination. However, the reports of Aidoo, Boateng, Kissi and Ofori (2016) and Ugwuadu (2017) do not present or take into consideration the performance of deaf learners in those examinations. This is perhaps because the population of deaf learners is low compared to their hearing counterparts. Gallaudet Research Institute (2004), Huber and Kipman (2012), Ataabadi, Yusefi and Moradi (2014) have shown that deaf learners perform weakly in the chain of numbers, vocabulary comprehension, scientific knowledge and reasoning. They lack experience with scientific reasoning and the mental models as well as ability to integrate new scientific facts. The findings mentioned above raises serious concerns about the academic achievement of the deaf in the science classrooms, their subsequent transition to tertiary institutions, workplace and family life.

Sangodoyin's (2011) research on teaching of scientific concepts found that inadequacy of resources for teaching, teachers' unsatisfactory use of resources and unsatisfactory performance in practical and field work were some of the factors militating against effective learning outcomes in Biology. Poor teaching method was observed by Ige (1998) as one of the causes of students' dismal performance in Biology. Therefore, Ige (1998) asserts that the conventional teaching strategy, which involves the sign/chalk-talk principles, is not suitable for teaching science-related concepts to deaf learners. Although the conventional method of teaching may be effective for efficiently disseminating a large body of content to a large number of students without hearing impairment, Aremu and Sangodoyin (2011) state that the one-way exchanges often promote passive and fail to stimulate student's motivation, confidence and enthusiasm. Teaching deaf learners require a series of influential teaching approaches in ways that promote meaningful learning, project solving, and critical thinking. When classrooms of the deaf are not stimulated and enriched with facilities and effective instructional techniques that could compensate for the loss in the sense of hearing, the academic achievement of such students tends to drop to a level that is worrisome to the student, parents, teachers and other stakeholders. In other words, the conventional teaching strategy (chalk-talk/sign) may present additional challenges to the teaching-learning process of deaf learners; thus, such non-technological pedagogic strategy may not be suitable for teaching basic digestive systems to deaf learners.

Kareem (2015) indicated that there is "an increase in the proportion of educators utilizing technology to enhance academic instructions with a proven record of success and effective teacher-students relationship as well as learning outcomes". Though, Kareem (2015) further noted that that technology in the classroom can be useful for teaching and learning enhancement as well as in pedagogical management but application and implication of technology in scientific or academic instruction for deaf learners in Nigeria particularly in Ibadan is yet to be well established in previous studies. Based on the foregoing, it is evident that there is a dire need to stimulate scientific teaching and learning with technology-based instructional strategies for deaf learners. This is because the power of technology in education is capable of removing constraints and enabling computer applications to provide learning support for deaf learners. Over the years, computer applications have found their way into the classroom to assist in the teaching and learning process as an instructional package known as Computer-Assisted Instruction (CAI). This is an instruction or remediation presented on a computer to illustrate a concept through attractive animation, sound, and demonstration. It can be referred to as a self-learning technique usually offline/online, involving interaction of students with programmed instructional materials. It is an interactive instructional technique in which a computer is used to present the instructional material and monitor the learning that takes place. It uses a combination of text, graphic sound and video in enhancing the learning process (Yenice, 2006).

According to Alessi and Trollip (2001), CAI packages are of five different types, which are the tutorial, simulation, educational games, drill and practice, and hypermedia modes. The tutorial mode of the CAI allows learners to receive immediate feedback to the questions and prompts. The tutorial mode of CAI is a learner-centred strategy that tests learners' mastery of subject contents from a simple to a more complex academic task (Özmen, 2008). Past studies that used the tutorial mode of CAI identified diverse effects of the computer package on students' learning outcomes. For example, Okoro and Etukudo (2001) applied CAI in teaching Chemistry; Egunjobi (2002) applied it in teaching Geography and Yusuf and Afolabi (2010) in teaching Ecology. They all confirmed that CAI is more effective in enhancing students' performance in other subjects than the conventional classroom instruction. However, none of these studies was conducted among deaf learners. Therefore, this study determined the effect of the tutorial mode of CAI on the achievement of deaf learners in Biology.

Project based Learning (PBL) is an instructional strategy currently gaining popularity in the field of science education. It is a product of recent advances in cognitive science and the new philosophy of science. It is a learner-centred approach that gives students opportunity to design and engage in scientific instructional activities that bring learners more closely to their true world (Thomas, 1999). For deaf learners, PBL facilitates an intimate connection and interaction with the natural world. In other words, deaf learners may experience natural integration with the ecosystem or the world around them. It is an instructional method that helps students to use the open-inquiry approach in learning to apply scientific knowledge in real-life situations (Ketpichainarong, Panijpan & Ruenwongsa, 2010), unlike the conventional method, in which students become passive in the teaching process, that does not promote project-solving and cognitive skills (Ronis, 2008).

The PBL involves an experimental learning process that is composed of data collection, investigation, observations, explanations and drawing conclusions (Bell, 2010). In some studies, PBL was found to have contributed positively to students' academic achievement (Cengizhan, 2007; Kanter & Konstantopoulos, 2010), meaningful learning in science modules (Kanter, 2010), students' individual learning (Chang & Tseng, 2011) and attitude towards science modules (Tortop & Özek, 2013). AltunYalçın, Turgut and Büyükkasap (2009), employed a quasi-experimental non-equivalent pretest-posttest research design and found significant differences in students' attitude toward physics, electricity achievement and scientific process skills between learners exposed to PBL and the control group. The finding of AltunYalçın, Turgut and Büyükkasap (2009) also support the idea that irrespective of gender, PBL improved the students' learning and enhances positive attitudes towards physics.

Gender issues in achievement of learners in sciences remain critical. Although research has consistently investigated the moderating effect of gender on students' engagements and achievement in scientific instructions, reports from various studies still remain largely inconclusive (Isa, 2005; Ekwueme & Umoinyang, 2005), while the influence of gender on achievement of deaf learners in Biology is yet to receive the needed research attention. Ifeako (2005) and Obeka (2007) reported that male students had higher achievements and interest scores in Chemistry than females. This was attributed to sex-role stereotyping, masculine image of science and female socialization process. Contrary to the findings of Obeka (2007), Ekwueme and Umoinyang (2005) reported that gender influenced achievement in favour of females, while Danmole and Femi-Adeoye (2004) found no significant difference in the achievement of students due to gender. It is based on this premise that this study examined the influence of gender on achievement in Biology among deaf learners.

Researchers, such as Yazdani and Godbole (2014) and Roy (2015), have noted that, irrespective of gender, achievement motivation is a critical factor that impacts science achievement. Although the submissions of Yazdani and Godbole (2014) and Roy (2015) were based on research experience among learners without disabilities, the finding motivated this study to examine the moderating role of achievement motivation among deaf learners. Generally, achievement motivation is expectancy of finding satisfaction in mastery of different and challenging performance (Roy 2015). Individuals with a greater degree of achievement motive are found to have a peculiar level of aspiration, while those with a lower degree of achievement motive will either not like to take any task in hand or will choose the simplest and easiest task or will choose the most difficult task where there is no chance for success. This implies that a learner whose achievement motive is stronger is more motivated to achieve, tries to maximize his own anxiety about failure, struggles hard for getting success and derives maximum pleasure from success (Roy, 2015).

Mahyuddin, Elias and Noordin (2009), Athman and Monroe (2004), Kobbeltvedt (2010) and Chan and Norlizah (2017) found that achievement motivation significantly and positively correlated with academic achievement. Mahyuddin, Elias and Noordin (2009) and kavyakishore (2013) state that learners with high motivation are ready and eager to learn and actively participate in scientific activities. Hence, such learner may have a higher level of achievement and satisfaction in sciences than learners who are less motivated. Individuals with a higher level of motivation display stronger academic self-efficacy and excellence, and are more likely to engage in self-regulating learning (Athman & Monroe, 2004).

Despite the volume of research reports based on the variables of interest in this study (computer-assisted instructions, project-based learning, achievement motivation and gender) on learners' performance in science subjects, there is no established study that considered the implications of computer -assisted and project-based learning instructional strategies for the academic achievement of deaf learners in Biology. Therefore, this study is anchored to the cognitive learning theory based on Bloom's taxonomy (Bloom et al., 1956), which assumes that there are some mental processes which have association with external environmental factors to influence a learning behaviour via the cognitive, affective and psychomotor domains. The outward exhibition of learning is not paramount to cognitivists; they focus more on mental processes and how learners can link environmental variables with mental images to arrive at meaningful learning experience. In line with the principles of the cognitivists, this study engaged the comprehension, synthesis, decision-making, abstraction, creative thinking, evaluative, analytical and problem-solving skills of deaf learners in the science classroom. This study is informed by the Cognitive Load Theory [CLT] (Sweller, Ayres, & Kalyuga, 2011) which is assumed to be suite situational constrained pedagogical strategies such as class periods which was used in this study. The CLT does not appreciate assumptions of conventional theories of learning, however, it focuses cognitive domains needed for functional working memory and long-term learning experience (Hoffman, Helversen & Rieskamp, 2013). Hence, this study determined the effects of computer-assisted instruction, project-based learning and conventional instructional strategies vis-à-vis the moderating effect achievement motivation and gender on their achievement of deaf learners in Biology.

2. Hypotheses

The following null hypotheses will be tested at 0.05 level of significance:

HO1. There is no significant main effect of treatment on deaf learners' achievement in Biology.

HO2. There is no significant interaction effect of treatment and gender on deaf learners' achievement in Biology.

HO3. There is no significant interaction effect of treatment and achievement motivation on deaf students' achievement in Biology.

HO4. There is no significant interaction effect of treatment, gender and achievement motivation on deaf students' achievement in Biology.

3. Materials and Method

The study adopted the pretest-posttest, control group quasi-experimental research design. A 3x2x2 factorial matrix was employed. It was made up of treatment at two levels (Computer-Assisted Instruction, Project-based Learning) and a control group (Conventional teaching method); these were crossed examined with achievement motivation (high and low) and gender (male and female) of the deaf learners who participated in the study.

The design is represented thus:

Experimental Group 1 (E1): O_1 X_1 O_4

Experimental Group 2 (E2): O_2 X_2 O_5

Control Group 3 (C): O_3 X_3 O_6,

where:

O_1, O_2 and O_3 represent pretest scores of the experimental groups 1 and 2 and the control group, respectively;

O_1, O_5 and O_6 represent posttest scores of experimental groups 1 and 2 and the control group, respectively;

X_1 represents the treatment for experimental group 1 (the tutorial mode of CAI);

X_2 represents the treatment for experimental group 2 (PBL); and

X_3 represents the control group for the conventional method of teaching of Biology.

4. Selection of Participants

The participants for the study were 30 Senior Secondary School II deaf learners who were purposively selected from 3 deaf high schools, represented as Schools A, B and C, in Ibadan, Oyo State, Nigeria. Schools A and C were located within the Ibadan North Local Government Area, while School C was situated at the centre of Ibadan North East Local Government Area. The participants from School A were exposed to the PBL strategy; those from School B to the tutorial mode of CAI; and those from School C were used for the control group –they were exposed to the conventional teaching approach. Ten deaf learners in the Biology classroom from each school were randomly selected through ballot to participate in the study.

5. Research Instruments

The Biology Achievement Test (BAT) was developed by the researcher to test the knowledge of the participants on the digestive system as designed in the Senior Secondary School Curriculum for Biology by the Nigerian Educational Research and Development Council (Federal Ministry of Education, 2009). The achievement test consisted of 40 multiple choice test items with options 'a, b, c and d' which were developed based on the Bloom's taxonomy. Example of the BAT items include: Mechanical digestion of food substances begins in the _______ (a) large intestine (b) stomach (c) mouth (d) small intestine. The BAT was validated using experts' review and the internal consistency reliability measure, which was calculated using the KR-20 formula. Thirty-one items survived the reliability measure at 0.78 and an average means difficulty value of 0.45. This implies that the test was neither too simple nor too difficult. Only the 30-item BAT was used to determine the pretest and posttest scores of the participants.

The Achievement Motivation Scale (AMS) was adapted from the Githuas' (2002) achievement motivation tool to measure the deaf learners' motivation towards Biology. The 26-item scale which had item like 'I am usually worried when I encounter a difficult problem in Biology that I couldn't understand at once' was designed in a 5-point Likert scale response format of "strongly disagree", "disagree", "undecided", "agree" and "strongly agree". Strong agreement with an item was given a score of 5 and strong disagreement was given a score of 1. The instructional guides (CAI Guide in Biology, PBL Instructional Guide in Biology and Conventional Instructional Guide in Biology) were developed by the author to guide the research assistants on the process of administering the treatment in the various groups. The guides delineate the roles of instructors and learners per time and how they interact with the treatment stimuli. The instructional guides had been earlier subjected to face and content validity through experts' review. The comments, observations, criticisms and suggestions of the experts were taken into consideration to improve the quality of the final instructional guides used for the experimental groups 1 and 2 as well as the control group.

6. Procedure for Data Collection

Approval to conduct the study was given by the University of Zululand from the Research Ethics Committee (UZREC 171110-030). The research obtained a permission to conduct the study in Ibadan from Local Education Authority of the Ibadan North and Ibadan North East Local Government Areas respectively. Both the Ethical approval from the University of Zululand and letter of introduction/permission from the Local Education Authorities to conduct the study in deaf senior secondary deaf schools were presented to the heads of the schools used in this study. Biology teachers from the selected schools were trained for 5 days on the interventions specific to their learners. Based on the training received on how to deploy the instructional guides for the purpose of the study, Biology teachers assisted in administering the BAT, AMS and treatment packages.

All participants were pretested with the BAT and AMS at the first week of intervention. The participants in the two experimental groups (CAI and PBL instructional strategies) were treated for a period of eight (8) weeks. Each treatment session lasted 45 minutes. The participants in the control group (Conventional Method) were given a placebo treatment; they were taken through concepts of the digestive system using the conventional mode of teaching and encouraged to do more on their own. The same instrument used during the pretest was deployed to assess the two treatment groups and the control group. The posttest was conducted on the eighth week of intervention.

7. Data Analysis

The data generated were subjected to statistical analysis using Analysis of Covariance to test the null hypotheses at 0.05 level of significance. Similarly, an estimates marginal mean difference of interventions was determined.

8. Results

HO_1. There is no significant main effect of treatment on deaf learners' achievement in Biology.

Table 1 reveals that there was a significant main effect of treatment on deaf learners' achievement in Biology ($F_{(2,28)} = 11.432$, $p < 0.05$; $\eta^2 = 0.574$). Therefore, the null hypothesis HO_1 was not accepted. This implies that the treatment had a significant main effect on achievement in Biology among the participants.

To further establish and determine the actual source of the observed significant main effect in ANCOVA, an estimated marginal mean difference presented in Table 2 indicated the performance of the participants in all the groups. The direction of decreasing main effect of treatment on the participants' achievement of in Biology is Computer-assisted Instruction, Project-Based Learning and the Control Group, that was on the conventional teaching method. Computer-assisted Instruction was more potent than Project-based Learning among the deaf learners in teaching the concept of the digestive system in Biology.

HO_2. There is no significant interaction effect of treatment and gender on deaf students' achievement in Biology.

Table 1 indicates no significant interaction effect of treatment and gender on the deaf learners' achievement in Biology ($F_{(2,28)} = 1.056$, $p > 0.05$; $\eta^2 = .110$).

Tests of Between-Subjects Effects

Dependent Variable: Post_Achievement

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	181.324[a]	12	15.110	5.150	.001	.784
Intercept	106.083	1	106.083	36.158	.000	.680
Pre_achievement	.041	1	.041	.014	.907	.001
Treatment	67.080	2	33.540	11.432	.001	.574
Gender	.505	1	.505	.172	.683	.010
Achievement_motivation	10.003	1	10.003	3.409	.082	.167
Treatment x Gender	6.195	2	3.098	1.056	.370	.110
Treatment x Ach_mot	8.609	2	4.304	1.467	.258	.147
Gender xAchiev_motivation	.474	1	.474	.162	.693	.009
Treatment x Gen x Ach_moti	22.806	2	11.403	3.887	.041	.314
Error	49.876	17	2.934			
Total	4130.000	30				
Corrected Total	231.200	29				

a. R Squared = .784 (Adjusted R Squared = .632)

Table 1 - Analysis of covariance of posttest achievement scores of treatment, gender and achievement motivation

Estimates

Dependent Variable: Post_Achievement

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CAI	13.736[a]	.699	12.262	15.210
PBL	10.514[a]	.677	9.086	11.942
Conventional	9.146[a]	.688	7.694	10.598

a. Covariates appearing in the model are evaluated at the following values:

Pre_achievement = 8.10.

Table 2 - Estimated Marginal Means

Therefore, the null hypothesis was not rejected. This finding implies that the interaction effects of treatment and gender had no statistically significant effect on achievement on the deaf learners in Biology.

HO3. There is no significant interaction effect of treatment and achievement motivation on deaf learners' achievement in Biology.

Table 1 also reveals no significant interaction effect of treatment and achievement motivation on the deaf learners' achievement in Biology ($F_{(2,28)}$ = .258, p > 0.05; η^2 = .147). Therefore, the null hypothesis was not rejected. This finding implies that the interaction effects of treatment and achievement motivation had no statistically significant effect on achievement of the deaf learners in Biology.

HO4. There is no significant interaction effect of treatment, gender and achievement motivation on deaf students' achievement in Biology.

Table 1 indicates that there was a significant interaction effect of treatment, gender and achievement motivation on the deaf learners' achievement in Biology ($F_{(2,29)}$ = 3.887, $p < 0.05$; η^2 = .314). Thus, the null hypothesis was not accepted. The estimated marginal means of post-achievement scores across treatment, gender and achievement motivation are presented in Figure 1 and Figure 2.

Figure 1 shows that the female participants had a higher mean score than their male counterparts across the two treatment groups but the male participants scored higher than the female deaf learners in the control group. Figure 2 reveals that the participants who had lower achievement motivation outperformed their counterparts with higher level of achievement motivation at both the treatment group 1 (CAI) and the control group, but performances were the same for all participants exposed to the Project-based Learning strategy.

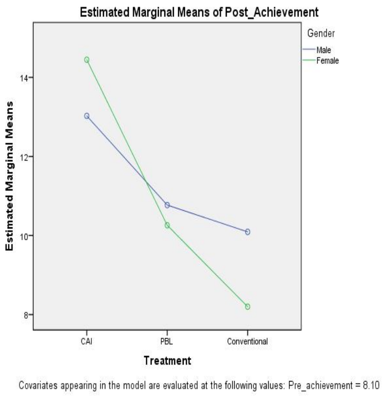

Figure 1 - Treatment against gender of participants

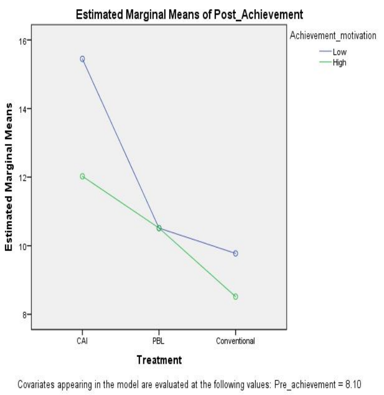

Figure 2 - Treatment against achievement motivation

9. Discussion

This study revealed that treatment significantly had effect on the achievement and performance of the participants on concepts of the digestive system. The participant exposed to CAI had higher posttest scores than those exposed to PBL and conventional teaching. This finding is in tandem with the findings of Yusuf and Afolabi (2010), Gürbüz & Birgin (2012), Nazimuddin (2015), Fırat, Gürbüz & Doğan (2016) and Gürbüz, Dede, and Doğan (2018). Based on the studies of Yusuf and Afolabi (2010) and Fırat, Gürbüz and Doğan (2016), current and geometric advances in new search for pedagogies to improve teaching, computer technologies with animation and simulation environment which learners can interact with and manipulate have great potential to enhance their learning abilities.

As observed in this study, Kareem (2015) as well as Gürbüz, Dede, and Doğan (2018) found that learners exposed to CAI, compared to learners taught, had increased ability to improve their academic performance and increased motivation to learning, as well as developed positive attitude towards abstract thinking and project-solving processes. This study also supports the findings of Yusuf and Afolabi (2010), Gürbüz and Birgin (2012) and Nazimuddin (2015), who confirmed that CAI is more effective in enhancing students' performance in other subjects than conventional classroom instruction. The participants exposed to the tutorial mode of CAI in this study experienced self-directed learning, which compensated for the loss in their sense of hearing with academic instructions and learning environment that appealed to the sense of sight.

The CAI approach used in this study proved more efficacious, as stated in Okoro and Etukudo (2001), Yenice (2006) and Gürbüz, Dede, and Doğan (2018), than other approaches used in the teaching of Mathematics and science instructions. Just like the studies of AltunYalçın et al. (2009), Bell (2010), Chang and Tseng (2011) and Ergül and Kargın (2014), this study found that PBL, though not as efficacious as CAI, improved the performance of deaf learners in Biology. There was a statistically significant difference in the posttest score of the participants in PBL and that of those in the control group. This study corroborates Ergül and Kargın (2014), whose study favoured the use of PBL for teaching Physics. The PBL differs significantly from conventional teaching because it provides learners with long-term activities and interaction. Krajcik and Blumen (2006) assert that PBL provides learners with enough time to interact among themselves and make connection between activities and their environment.

The finding of this study showed no significant interaction effect of treatment and gender or interaction effect of treatment and achievement motivation on deaf learners' achievement in Biology but when the three dependent and moderator variables were combined, there was interaction among the variables. This finding supports Ekwueme and Umoinyang (2005), Obeka (2007), Yazdani and Godbole (2014) and Roy (2015), who attribute gender differences to various models of teaching and social interaction. Specifically, Ekwueme and Umoinyang (2005) reported that gender influenced achievement, while Danmole and Femi-Adeoye (2004) revealed that achievement of both males and females could be affected by teaching and learning styles. This study supports Liu and Zhu (2009), who found significant differences in achievement motivations of male and female senior high school students; the male students had higher achievement motivations than the female students.

10. Conclusion and recommendations

This study concludes that the Computer-Assisted Instruction (CAI) and Project-based Learning were more effective than the conventional classroom method of teaching biological concepts to deaf learners. However, CAI was found to be the best approach to use by teachers to teach scientific concepts to deaf learners. It creates an opportunity for the learners to interact with and use technology for their learning. The CAI and PBL are learner-centred instructional strategies that enhance active participation for learners in science classrooms.

Based on the findings, schools should encourage deaf learners to actively participate in science by adequate provision of technologies and practical equipment that can compensate for the loss of the sense of hearing. Teachers should also teach using computer-assisted instructional packages that learners can have access to any time, at school or at home. There is an urgent need for science teachers to be adequately trained on the use of CAI in teaching, particularly for teaching deaf learners in preparation for the world-driven by technology.

Acknowledgements

The author appreciates all research assistants, teachers and deaf learners who participated in this study.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 33-43

Making the School Smart: The Interactive Whiteboard Against Disparities in Children Stemming From Low Metacognitive Skills

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(submitted: 29/11/2019; accepted: 17/03/2020; published: 30/04/2020)

Abstract

The demand for an increasingly differentiated education, which takes into account the individual differences of children to stimulate effective learning, accompanies the introduction of new technologies at school. Amongst these, the Interactive Whiteboard (IWB), which allows multimodality and sharing of contents, is one of the most widespread tools in schools. The aim of the study was to test with a sample of primary school children the impact of a teaching session with the use of the IWB (vs. traditional lessons) on knowledge performance. In addition, we were interested in investigating the role of metacognition as a potential moderator on learning effects. Our results revealed an advantage of IWB use in learning achievement. Notably, the increase in learning outcomes only occurred among children with low metacognitive skills. This shows that new technologies can play an important role both per se and in supporting learning processes, especially of less metacognitive students, therefore contributing to reduce the gap between children with differential metacognitive skills. The results are analyzed in light of the important role in the nowadays world of Information and Communication Technologies, which can become an extremely relevant and appealing educational and cultural compensation tool.

KEYWORDS: ICT, metacognitive learning, IWB, smart teaching

DOI
https://doi.org/10.20368/1971-8829/1135191

CITE AS
Cadamuro A., Bisagno E., Di Bernardo G.A., Vezzali L., Versari A., (2020), Making the School Smart: The Interactive Whiteboard Against Disparities in Children Stemming From Low Metacognitive Skills. Journal of E-Learning and Knowledge Society, 16(1), 33-43. https://doi.org/10.20368/1971-8829/1135191

1. Introduction

Recent years witnessed the emergence of increasingly differentiated educational needs. The school should, therefore, be able to offer children a range of educational opportunities, involving the use of different languages, modalities, and supports. A tool that is acquiring growing importance in everyday life, and in schools, is represented by new technologies, that allow the possibility of making use of animations and videos in interacting with dynamic environments and in which the child can be a passive spectator as well as an active participant. With new technologies, knowledge should not be conceived as pre-packaged instructions or concepts to be transmitted; instead, it can be a joint construction of teachers and children (Solomon, 1993; Tucci & Antonietti, 2009). Digital devices offer the possibility of increasing the centrality of students by transforming the traditional classroom environment into a student-centered collaborative environment and bringing the school closer to communicative and learning forms typical of the so-called ‘digital natives’ (Prenksy, 2001; Somyürek, Atasoy, & Özdemir, 2009).

ICT can allow teachers to create opportunities in which students can learn by doing, helping them visualize difficult-to-understand concepts (Mouza, 2005). Clements and Nastasi (1993) argue that, in addition to promoting children’s learning, technology can foster social interaction, peer teaching, and collaboration.

Nowadays, a revision of the curricular contents and an adaptation of the knowledge in order to respond to the characteristics and demands of children and society is crucial (Herrington & Kervin, 2007; Silva, 2009). It is important to present students with authentic tasks (Jonassen, 1992), namely meaningful, contextual tasks, which have adequate levels of complexity, relevance and usefulness in everyday life. Introducing the new technologies in the school provides the opportunity for change, not only at the ‘practical’ level of educational tools to manage learning processes and teaching.

Instead, change can allow to reflect on these processes and innovate them consciously and critically.

The reforms that led to the massive introduction of Information and Communication Technologies (ICT) within our classrooms are causing a significant change in the world of education. ICT can become potential agents of change capable of influencing the educational setting, which includes physical environment, behaviors and relationships between the various actors, tasks and activities, relational and operational climate, motivations and expectations (Carletti & Varani, 2007). This change is increasingly directed at moving away from the exclusive use of traditional teaching, understood as teaching that uses paper material and in which knowledge is presented in a standardized way. Teaching should be able to use and integrate these new technological tools, shifting the focus from the school system to the individual.

The full potential of technology is realized when it improves the effectiveness of a learning environment, when it supports profound and meaningful learning, and when it realizes an active, constructive, collaborative, authentic, and intentional teaching approach (Jonassen, Howland, Marra, & Crismond, 2008; Scardamalia & Bereiter, 2006). ICT should not be understood as 'teaching machines', but as a 'tool' that allows the student to co-construct his/her own learning path, to socialize it and therefore to personalize it with respect to personal cognitive styles (Battro, 2010; Rivoltella, 2008). In other words, it is not sufficient to introduce ICT in the school and use them as traditional tools. Instead, ICT should match the characteristics of the individual, and favor an active and efficient learning process. The challenge, therefore, does not concern the introduction of ICT per se, which is quite straightforward. Instead, it relates to the ability to use ICT to stimulate students and their learning process as efficiently as possible, taking advantage of their potential and allowing them to overcome their learning weaknesses.

2. ICT and metacognition

Technological tools can facilitate taking awareness of one's own mental processes. In this sense, these tools can make visible and concrete the choices, the mental associations and the operating procedures that characterize students' psychological processes (Tondeur, Van Braak & Valcke, 2007; Varani, 2007).

Indeed, the reflection on one's own mental processes while learning is a key element of metacognition. Metacognition is defined as the learners' knowledge of their own cognitive processes (Dignath, & Büttner, 2008) and mental functioning (Flavell, 1979), that is what one knows about how his/her and other people's minds functioning. It also refers to the different forms of control that can be implemented before, during and after the execution of a task (Brown, 1987), namely planning how to approach a task, anticipating how successful it will be, choosing the right strategy, assessing progress and, if necessary, selecting different and more appropriate learning strategies.

The interest generated by metacognition is largely due to the fact that it is considered a powerful predictor of the learning performance of children (Roebers, Krebs, & Roderer, 2014). Although not numerous, there are studies that investigated the role of metacognition and ICT in learning environments (see Cadamuro, Bisagno, Pecini, & Vezzali, 2019 for a review). The literature reveals evidence that metacognitive skills can facilitate learning in environments characterized by new technologies (Ramirez-Arellano, Bory-Reyes, & Hernández-Simón, 2019; Wall & Higgins, 2006).

Technological tools can be an important support for metacognitive reflection because they allow recording the actions performed by the individual, therefore providing the student with 'personal' feedback, which is a response about the physical and conceptual operations s/he actually performed (Mercer, Hennessy, & Warwick, 2010). Moreover, new technologies allow asking the student questions about his/her own cognitive activity with the aim to increase monitoring and making this reflective attitude a habit when facing learning tasks (Antonietti, 2011). Some technological tools can encourage and support social interaction and cooperation, indirectly favoring a 'distributed' and shared metacognition. For example, discussion, comparison and conversation are excellent tools to raise awareness about the mental processes involved in an activity (Antonietti & Colombo, 2008). Therefore, new technologies can be used to support the development of metacognition, by helping students manage information in different ways, improving their way of taking notes and organizing their learning.

In line with the aforementioned studies, the review by Cadamuro et al. (2019) highlights that ICT and metacognition are in a bi-directional relationship, exerting reciprocal influence on each other. Importantly, this review also highlighted a theoretically more interesting and challenging result, that is e-learning environments can have beneficial effects on learning outcomes when they are structured in a way to take advantage of metacognition. In particular, when individuals are provided metacognitive guidance, they are better able to take advantage of ICT, with resulting benefits on the learning performance (Kramarski & Gutman, 2006). In other words, ICT and metacognition can jointly contribute to defining the optimal psychological processes relevant to learning. Indeed, students with better metacognition take advantage of more effective skills and strategies when using technologies. Metacognition, therefore, supports the individuals' awareness with respect to the knowledge and skills that are necessary to achieve certain goals, where to focus the attention and where to adjust efforts.

However, what happens when ICT is introduced without ad-hoc metacognitive training that can optimize their use? Are there generalized learning benefits due to the use of ICT, or these learning benefits will eventually be shown only by individuals with certain metacognitive characteristics? In other words, which is the outcome of the interplay of ICT and individual metacognition skills on learning? Finding this is precisely the aim of the present study. To do so, we focused on a widespread ICT tool in schools, that is the Interactive Whiteboard (IWB).

3. The Interactive Whiteboard in classrooms

The use of IWB in schools has increased in recent years all around the world (Šumak, Pušnik, Heričko, & Šorgo, 2017). The IWB represents an opportunity for easy and immediate use of digital technologies in class (Betcher & Lee, 2009), a consideration that has contributed to increasing its popularity amongst many teachers (Murcia, 2014). IWBs were regarded as one of the most revolutionary instructional technologies for different educational levels (Türel & Johnson, 2012). They can offer several pedagogical benefits such as facilitating the integration of new media, enhancing the interactivity, fostering learners' engagement in lessons (Koenraad et al., 2015), and dialogue (Dostal, 2009; Kerawalla, Petrou, & Scanlon, 2012).
Students and teachers generally perceive IWB as a positive addition to the classroom learning environment (Hall & Higgins, 2005; Manny-Ikan, Dagan, Tikochinski, & Zorman, 2011). In line with this trend, the IWB has been spreading over the last few years also in Italy, mainly because of the massive national and local investment plans that have made it an important part of the digitalization process of Italian schools.

During the second half of the '90s, Italian ministerial policies proposed the "Didactic Technologies Development Programs" [Programmi di Sviluppo delle Tecnologie Didattiche], in which ICT were introduced to facilitate active and cooperative work and to reduce the gap between the class and school and the outside world (MIUR, 1995). In 2002, the "National Plan of training of teachers on information and communication technologies" [Piano nazionale di formazione degli insegnanti sulle tecnologie dell'informazione e della comunicazione", ForTic] was proposed with the aim of promoting technical knowledge but also an effective use of technology. In 2007, the "National Digital School Plan" [Piano Nazionale Scuola Digitale, PNSD] was launched to promote new practices and new learning models. The plan passes through three main initiatives: the IWB action, which provides funding for the purchase of interactive multimedia whiteboards and the related training of teachers; the Cl@ssi 2.0 action, which aimed to assess the effective integration of technologies in schools with a shift of focus to the effectiveness of technologies in changing contexts and learning processes; and the Digital School Publishing Action, which aims to transfer teaching resources from paper to digital format, with the possibility for students to edit, comment, and interact with the text. In 2016, the PNSD, within the reform of the School [La Buona Scuola], aimed to guide schools on a path of innovation and digitalization and introduced ICT in schools, spreading the idea of lifelong learning and extending the concept of school from the physical place to virtual learning spaces. According to the findings of the MIUR Technological Observatory, in the 2014-2015 school year, 70% of the classes were connected on-line and 41.9% were equipped with an IWB (MIUR, 2015). Currently, in Italy, the IWB is a very common tool. It is estimated that there are about 70,000 IWBs. The wide spread of the IWB in the classroom is due to its potential to encourage collaboration by creating a shared learning environment suitable for teaching strategies with either the whole classes or small groups (Bennett & Lockyer, 2008). The IWB can also create new opportunities for students to learn through multimedia or interactive resources (Alvarez, Salavati, Nussbaum, & Milrad, 2013; Gillen, Littleton, Twiner, Staarman, & Mercer, 2008; Wall, Higgins, & Smith 2005).

Since the large-scale introduction of the IWB in schools, there has been an extensive body of research on its educational uses. Researchers primarily focused on two aspects of the IWB use in schools: IWB as a tool that promotes a more effective teaching process, and as a tool that supports students' learning (Morgan, 2012). Many studies have shown that the use of IWB has a positive effect on student learning (Amiri & Sharifi, 2014; Digregorio & Sobel-Lojeski, 2010; Wall et al., 2005; Warwick, Mercer, & Kershner, 2013). The literature suggests that the IWB offers the opportunity to better match learning to different student learning styles (global, local, visual, verbal, etc.) and this allows teachers to customize teaching according to the individual characteristics of the students (Wall et al., 2005). Therefore, it can help teachers in meeting students' diverse learning needs and provide more opportunities for interaction and discussion in the classroom, also when compared to other ICT (Luo & Yang, 2016; Smith, Higgins, Wall, & Miller, 2005). The use of IWB also brings some significant changes in the teaching process in terms of time-saving for teacher's preparation of the teaching material, saving of the prepared content for later re-use, rapid transitions within and between the presented contents, fast retrieval of already displayed content, thus enabling a teacher to respond to students' needs in case of comprehension difficulties (Bennett & Lockyer, 2008; Cutrim Schmid, 2008).

Students, on their side, have a positive perception of the IWB, to the extent that it can motivate learning and make lessons more enjoyable (Balta & Duran, 2015; Glover, Miller, Averis, & Door, 2005; Şad, & Özhan, 2012; Smith et al., 2005; Wall et al., 2005). Indeed, the visual appeal is noted as one of the main contributors to motivation (Smith, Hardman, & Higgins, 2006) and there is a general agreement that the IWB has a positive effect on student motivation (Davidovitch, & Yavich, 2017; Higgins, Beauchamp, & Miller, 2007; Morgan, 2012; Slay, Siebörger, & Hodgkinson-Williams, 2008; Smith et al., 2005). It has also been reported that the IWB promotes students' interest and their sustained concentration (Glover & Miller, 2007).

Therefore, the literature on the IWB generally supports the idea that it can positively impact students' perception, motivation, engagement, attention and learning styles (Fekonja-Peklaj & Marjanovicˇ, 2015).

Finally, the IWB can be a dynamic and manipulative object that supports socially shared cognition, helping students working together (Hennessy, Deaney, Ruthven, & Winterbottom, 2007). Warwick and colleagues (2013) argue that the IWB can promote the development of children's ability to reason collectively and to regulate their joint activities. This peculiarity may improve the quality of the relations between student and teacher, but also among classmates (Glover et al., 2005), increasing the students' disposition to share acquired knowledge and to learn from their own and others' mistakes (Smith et al., 2006).

Despite all these positive effects, some studies found that the effects of IWB aided teaching were weak, invalid, or even detrimental. For instance, Torff and Tirotta (2010) stated that claims about the motivation-enhancing effects of the IWB appear to be somewhat overstated. Luo and Yang (2016) concluded that the usefulness of the IWB and its effects on willingness to learn are not as clear. Fekonja-Peklaj and Marjanovič-Umek (2015), based on the content analysis of teachers' and pupils' answers, reported both positive (dynamic display of the content, pupils' attention and motivation, immediate feedback) and negative aspects of the IWB (technical difficulties, a frontal way of teaching, teacher's lower control over pupils' work). Kervin and colleagues (2010) emphasized that the higher motivation of students to learn with the ICT does not necessarily mean that their motivation is focused on the content, but can instead be directed to the device used by the teacher. Above all, questions remain about the relationship between the IWB, students learning and scholastic achievement. In fact, the literature presented above explored many outcomes related to actors of the educational process. Surprisingly, however, studies examining the impact of IWB on learning achievement are scarce (Bidaki & Mobasheri, 2013; Hockly, 2013; DiGregorio & Sobel-Lojeski, 2010). Indeed, when the connection between the use of the IWB and the students' knowledge performance was explored directly, findings were mixed: while some studies showed a positive effect of the IWB on learning achievement (Chen, Chiang, & Lin, 2013; Maher, 2011; Swan, Schenker, & Kratcoski, 2008; Zittle, 2004), others did not find supporting evidence (Higgins, Beauchamp, & Miller, 2007; Moss et al. 2007; Swan, Kratcoski, Schenker, & van't Hooft, 2010). Clearly, if the IWB has positive effects on the educational process, this should also be found with respect to one of its main outcomes, that is learning achievement.

4. The research

Despite the vast body of research that investigated the educational impact of new technologies, and, in particular of the IWB, some questions remain open. In fact, there still is equivocal evidence with respect to the impact of the IWB (Smith et al., 2005) upon learning achievement. For this reason, we carried out a study with a sample of primary school children, aimed at evaluating the impact of a teaching session with the use of the IWB on knowledge acquisition. In addition to using the IWB, we identified a potential moderator that, as described above, is directly relevant to learning: metacognition. More precisely, an experimental group used the IWB, while a control group went through traditional teaching with the use of a traditional blackboard. Before the lesson, participants were administered a measure assessing their metacognitive skills, allowing us to test their role as a moderator of learning with new (IWB) vs. traditional technologies.

First, we expected an advantage of IWB use, such that performance scores should be higher when using the IWB than when being exposed to the traditional lesson. Our second prediction was that greater metacognitive skills will be associated with better performance in the evaluation test. More directly relevant for our research, based on the literature reviewed, we predicted no difference in learning between participants with high metacognitive skills in the experimental vs. control group. Indeed, individuals with high metacognitive skills should be able to process information more efficiently and to better integrate it with pre-existing knowledge, independently on the instrument by which teaching occurs. In contrast, we predicted the role of the IWB in favoring learning in those with less metacognitive skills, who may be less able to reflect on their mental processes and integrate information with pre-existing knowledge. When using the IWB, however, the characteristics of the tool, including the different channels (e.g., visual, audio) by which information is conveyed, may stimulate individuals in making better use of their scarce metacognitive skills. The variety of channels by which the information is presented can allow integration of information, that, in their absence, is up to metacognition. In other words, using the IWB might buffer the effects of low metacognitive skills on performance, and allow a similar performance of participants independently on their individual level of metacognitive skills. We, therefore, expect an interaction between IWB use and metacognition, such that IWB use (experimental group) will lead to better performance (compared to the control group) only among participants with low levels of metacognitive skills.

4.1 Participants

One hundred and eighty-four Italian children (89 males, 96 females) took part in the study. Participants were enrolled in fourth- and fifth-grade classes from four primary schools located in Northern Italy. Parents provided consent for their children to participate.

4.2 Materials and Methods

To properly compare learning as determined by the use of the IWB, we selected two topics that children had not yet faced in their school curriculum and designed a traditional and an IWB version of them. The first topic related to 'Children's Rights' (Grade 4) and the other to the 'Italian Constitution' (Grade 5). Both lessons were presented either in a 'traditional' type mode, where the lesson was conducted according to a verbal approach using the traditional blackboard (control group) or with a multimedia lesson method via the IWB (experimental group). The pupils of each class were divided into groups of four, with each small group randomly assigned either to the experimental group or to the control group.

Among the activities that we proposed to children, there were stories, nursery rhymes that dealt with children's rights and the Italian Constitution, cartoons, some videos based on the film 'Iqbal, children without fear (2015)' (which is about the story of Iqbal Masih, a Pakistani child who rebelled against child labor), images and documents and videos taken from Unicef, Amnesty International and Save The Children. The lessons in the experimental group were created by taking into consideration some important aspects in order to prevent cognitive overload and fatigue in children:

- the graphic character had to be easy to read and facilitate understanding;
- the concepts had to be expressed through short, simple sentences or via keywords;
- each keyword had to be accompanied by a corresponding image to facilitate reading through two different channels;
- the videos inserted had to be short and not contain too much information.

In the traditional lesson, the contents were presented with the same words used in the experimental group, and the same keywords and phrases were reported on the traditional blackboard; the content of the videos used in the experimental group was reported orally.

One group at a time, all the children attended either the lesson with the IWB or the traditional lesson. In the lesson with the IWB, we used some functions, such as the 'felt pen' function, to emphasize and highlight words during the oral explanation. The same was done in the traditional lesson, where the same words were underlined with chalk or felt-tip pen. Both lessons were presented in the most homogeneous possible way, to exclude confounding variables that could influence the comparison between conditions.

In both groups, (traditional or IWB) at the end of the lesson, the children carried out a small group activity which consisted of describing what fundamental rights, or what type of government, citizens (adults and children of different cultures and religions from Earth) of an imaginary planet should adopt. In order to assess the metacognitive skills of children, before presenting them with the lessons, we asked their teachers (one per class) to evaluate them through the Teachers Metacognitive Questionnaire (Carr & Kurtz, 1991). This instrument is composed of nine items, assessing students' strategic awareness and monitoring. In filling the tool, the teachers had to evaluate on a Likert scale (from 1 to 5 points) each child in their class on items such as: 'To what extent is this child aware that there are alternative strategies?'; 'To what extent is this child aware of how the different strategies can be used?'. For each child, the items were combined in a composite score of metacognitive skills (alpha = .91).

Once the lesson was completed, both the control and the experimental groups were administered (upon agreement with the teacher and taking into account children's Grade) a learning assessment test, that each child performed individually. For the 'Children's Rights' topic, children were administered a multiple-choice test with 15 items; for the 'Italian Constitution' the multiple-choice items were 20. Items were averaged to form for each child an individual index of performance (alpha = .73).

4.3 Results

An independent samples t-test showed no differences in metacognition across conditions, $t(184) = 1.47$, *ns*. In other words, participants presented comparable levels of this ability within the experimental and control groups, therefore making the groups comparable in terms of this variable and allowing us to use it as a moderator.

In line with our first prediction, condition affected participants' knowledge performances: participants in the IBW condition displayed a higher performance ($M = 0.78$, $SD = 0.14$) compared to participants in control condition ($M = 0.73$, $SD = 0.18$), $t(184) = 2.06$, $p < .05$. Therefore, the use of the IWB favors knowledge performance.

In order to test the moderating effect of metacognition in the relation between teaching modality and knowledge performance, a regression analysis using PROCESS macro for SPSS (Hayes, 2013; Model 1) was conducted. Specifically, condition (dummy coded: -1 = control condition, 1 = experimental condition), children's metacognitive skills and the interaction term were included as independent variables. The individual index of knowledge performance represented the dependent variable. All independent variables were centered to the relative mean in order to avoid multicollinearity.

Results showed that predictors explained a significant and high amount of variance of the criterion variable, $F(3, 180) = 59.50$, $p < .001$, $R^2 = .50$. In line with our second prediction, a significant main effect of metacognition ($b = 0.11$, $SE = .01$, $p < .001$) emerged, revealing that higher levels of metacognitive skills were associated with better knowledge performance. This result is consistent with literature showing the powerful role of metacognition in learning, and further reveals the reliability of the instrument and of teachers' evaluations of children's metacognitive skills. Interestingly, when taking into account metacognition, condition was not associated with performance ($b = 0.01$, $SE = .01$, *ns*). In other words, when condition and metacognition were simultaneously included in the regression equation along with their interaction, only metacognition was predictive of performance, revealing that metacognition, more than teaching modality, is especially relevant to learning. This result further adds to the explanatory role and relevance of metacognition.

Results also revealed a significant interaction between condition and metacognitive skills ($b = -0.03$, $SE = .01$, $p < .01$). Supporting our predictions, simple slope analysis (see Figure 1) revealed that condition led to better knowledge performance among children low ($b = 0.04$, $SE = .01$, $p < .01$), but not high ($b = -0.01$, $SE = .01$, *ns*) in metacognition. In other words, being assigned to the experimental group, that is using the IWB, favored a better performance only among individuals with low metacognitive skills, who indeed were those that had more to gain from the use of ICT. Also in line with our hypotheses, Figure 1 shows how performance for individuals high in metacognition is constantly higher, however, the use of IWB reduces the gap between participants with high vs. low metacognition.

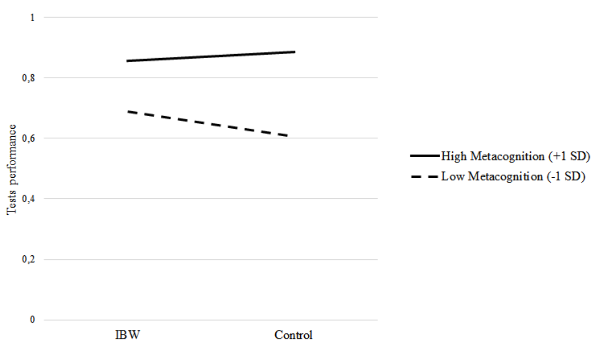

Figure 1. Test performance as a function of condition at high (+1 SD) and low levels (-1 SD) of metacognition.

5. Discussion and Conclusions

The aim of the present study was to test the impact of new technology, namely the IWB, on children's knowledge performance. Importantly, we considered the role of metacognition, that is a psychological variable directly relevant to learning, exploring whether the effect of learning with the IWB depends on children's metacognitive skills.

Our results revealed an advantage of new technologies in learning achievement: children's performance was better when using the IWB than when being exposed to the traditional lesson. This advantage may be due to the fact that, as stated in the literature, the IWB can improve students' motivation (Davidovitch, & Yavich, 2017; Higgins, Beauchamp, & Miller, 2007; Morgan, 2012; Slay et al., 2008; Smith et al., 2005) and promote interest and sustained concentration (Glover & Miller, 2007).

A further relevant finding is that higher levels of metacognitive skills were associated with better knowledge performance. This result is consistent with literature showing the crucial role of metacognition in knowledge performances (Barak, 2010). Interestingly, when considered together, only metacognition (and not condition) was predictive of performance, therefore showing the need to consider this key variable when learning is implied.

However, the most interesting result, both at the theoretical and at the practical level, is that the IWB favored a better performance only among individuals with low metacognitive skills. Students with lower metacognition are, therefore, those that benefited the most from using ICT. Note that students with high metacognition competences performed better in both conditions, but the use of the IWB reduced the gap in performance between participants with high and low metacognition. These less metacognitive students (that is, those who are less able to reflect on their cognitive processes and to regulate them) through the IWB can better integrate, also with the help of different codes (verbal, visual, etc.), the incoming information with that they already have. In other words, the IWB mitigates the detrimental effects of low metacognitive skills on learning and allows a similar performance of participants regardless of their individual level of metacognitive competences.

These results reveal that new technologies can play an important role, especially in supporting and stimulating the learning processes of those students with less metacognitive skills. This finding is consistent with the results of a study that aimed to evaluate the effect of the Flipped Classroom (FC) on learning performance in primary school children (Lazzaretti, Cadamuro, Di Bernardo, Pecini, 2019). The FC was found to be effective in improving learning especially for pupils with low metacognition. Thus, it seems that children with poor metacognition skills are able to make up for their shortcomings because of ICT.

These findings point to the role of new technologies as an educational and cultural compensation tool, that provides students lacking in metacognition with support for processing and memorizing information more effectively. In this sense, a multimedia learning environment allows students to personalize their learning by making the contents close to their learning styles (Wall et al., 2005). Through the use of new technologies, contents can be manipulated and customized, allowing the teachers to respect the different cognitive styles of the students, thus favoring inclusive teaching. The IWB can, therefore, be a tool that benefits both students and teachers if used with sufficient awareness.

Moreover, the IWB facilitates motivation and interaction (Davidovitch, & Yavich, 2017) and promotes an active attitude of students, who become better able to regulate their cognitive and emotional processes. Finally, the IWB can promote knowledge sharing even among peers through discussion and comparison, processes that facilitate students' awareness of their mental processes involved in an activity.

These considerations lead us to recognize the importance of teachers in the effective use of new technologies. Assuming that student achievement will automatically increase with technology use may be wrong and dangerous since it can lead to overly optimistic and unrealistic expectations. Although there are many studies that report positive effects of the IWB when used in the classroom, the IWB effectiveness depends on how it is used by teachers in the teaching process (Kelley, Underwood, Potter, Hunter, & Beveridge, 2007; Polly & Rock, 2016; Türel & Johnson, 2012).

Some studies and reviews have shown that a greater effectiveness of ICT is found when the teacher employs a variety of teaching strategies and offers multiple learning opportunities; when the teacher is trained in the didactic use of the computer and when s/he favors peer learning processes; when optimizing the teacher-pupil feedback; and when the student has the opportunity to take control over the learning process. (Higgins, Xiao & Katsipataki, 2012; Vivanet, 2014).

The IWB has been shown to be an asset to a classroom if teachers are willing to invest their time in learning how to use it with profit. This also includes in some cases changing their teaching style, from more traditional teaching to new pedagogical practices (Celik, 2012; Mercer, Hennessy, & Warwick, 2010) which integrate technology into lesson planning and conducting (Comi, Gui, Origo, Pagani, & Argentin, 2016). Betcher and Lee (2009) reported that teachers generally follow three stages when approaching the use of the IWB. In the first stage, teachers propose the same content using traditional methods. In the second stage, they introduce certain changes but without in-depth alteration in teaching methods, and only in the third stage innovative pedagogy is applied. Many teachers seem to be unaware of the ICT potential in promoting children's learning. This reflects in the use of the IWB as a big visual board or display tool (Kearney & Schuck, 2008), rather than as a learning environment for the co-construction of contents. Teachers with constructivist oriented pedagogical beliefs are significantly more likely to use IWB than transmission-oriented teachers, however, the strongest determinant of usage is whether the technology is immediately accessible or not (Burke, Schuck, Aubusson, Kearney, & Frischknecht, 2017). In fact, the IWB can be perceived as easy to use, interactive, immediate, visual and matching the students' digital culture. However, some authors argue that this effect may be due to novelty that any new ICT can bring, and may decrease over time when learners become used to the technology (Kearney and Schuck 2008; Mariz, Stephenson, & Carter, 2017; Slay et al., 2008), especially if teachers do not know how to integrate this methodology into didactic proposals that stimulate reflection and metacognitive monitoring.

Our results help to address this debate, showing that the effect of the IWB may be related to psychological processes relevant to learning (i.e. metacognition) rather than to novelty. Future studies should, therefore, explore how both aspects (metacognition and novelty), independently or interactively, contribute to qualifying the effect of the IWB.

From an applied point of view, the results of our research confirm the need to use ICT to encourage deeper and dialogic interactions in which pupils articulate their thinking and reflect on their learning. ICT provides the opportunity to create stimulating learning communities and to foster the growth of metacognitive reflection, given that metacognition develops also because of social interaction. The introduction of new technologies brings the opportunity for the school to get 'smarter and smarter' because it leads to reflect on the processes of the learning-teaching process and on how to consciously and critically innovate it.

To conclude, our study shows that the IWB serves who needs it more, that is individuals with fewer competencies to take advantage of a traditional lesson. If this result will be replicated, it will support the important role of ICT in modern teaching, that is providing all children with the possibility to learn how to learn, ultimately improving their school performances and more generally life achievements. Finally, given the role that ICT has in supporting those who need it the most, new technologies represent a promising tool in the fight against educational poverty.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 44-54

Deep learning approach for predicting university dropout: a case study at Roma Tre University

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(submitted: 29/11/2019; accepted: 13/02/2020; published: 30/04/2020)

Abstract

Based on current trends in graduation rates, 39% of today young adults on average across OECD countries are expected to complete tertiary-type A (university level) education during their lifetime. In 2017, an average of 10.6% of young people (aged 1824) in the EU-28 were early leavers from education and training. Therefore the level of dropout in the scenery of European education is one of the major issue to be faced in a near future. The main aim of the research is to predict, as early as possible, which student will dropout in the Higher Education (HE) context. The accurate knowledge of this information would allow one to effectively carry out targeted actions in order to limit the incidence of the phenomenon. The recent breakthrough on Neural Networks with the use of Convolutional Neural Networks (CNN) architectures has become disruptive in AI. By stacking together tens or hundreds of convolutional neural layers, a "deep" network structure is obtained, which has been proved very effective in producing high accuracy models. In this research the administrative data of about 6000 students enrolled from 2009 in the Department of Education at Roma Tre University had been used to train a Convolutional Neural Network based. Then, the trained network provides a predictive model that predicts whether the student will dropout. Furthermore, we compared the results obtained using deep learning models to the ones using Bayesian networks. The accuracy of the obtained deep learning models ranged from 67.1% for the first-year students up to 94.3% for the third-year students.

KEYWORDS: University Dropout, Deep Learning, Convolutional Neural Network, Educational Data Mining, Bayesian Network

DOI
https://doi.org/10.20368/1971-8829/1135192

CITE AS
Agrusti F., Mezzini M., Bonavolontà G., (2020), Deep learning approach for predicting university dropout: a case study at Roma Tre University.Journal of E-Learning and Knowledge Society, 16(1), 44-54. https://doi.org/10.20368/1971-8829/1135192

1. Introduction

Academic failure at Higher Education (HE) level can be divided into four main categories (Tanucci, 2006): a general irregularity in the achievement of credits / exams completion, the extended duration of the student condition (so-called *out-of-school education*), the lack of linearity of the career (e.g. course transfers) and finally the actual leaving of the learning path that leads to the exit from the university system without obtaining the degree. Of course, several are the variables that influence students' decision to leave university (Krause, 2005), and according to which prevails, even the dropout definition can vary, according to literature.

The definition chosen in this paper is the one proposed by Larsen and other researchers in 2013 where dropout is defined as "the withdrawal from a degree course before it is completed" (p. 18). This definition also includes withdrawal from individual courses of study but not students leaving due to pregnancy, illness, etc., i.e. for all those causes that can be attributed to very specific reasons and temporary duration. The phenomenon of university early leaving has several negative effects other than its consequences at a personal level. On a general level, low completion rates of a university course could lead to a bottleneck of the skills in a cohort of the population, that can have consequences on the economic and social level, decreasing the competitiveness, innovation and productivity of a country.

For decades, one of the most used and discussed models have been Tinto's "student integration" model, which underlines the importance of the academic and social integration of students in predicting the phenomenon of early school leaving. This model envisages five different approaches to integration: psychological, sociological, economic, organizational, and the interactionalist approach (Tinto, 1975, 2010). One of the other main models is the one proposed by Bean (Bean, 1988), the "student attrition" model, based on the attitude-behavior of the student, which measures individual and institutional factors and evaluates their interactions to predict university dropout (Bentler & Speckart, 1979). Another interesting model of student/institution integration is the Pascarella model (Pascarella & Terenzini, 1980), which emphasizes the crucial importance of student success of having informal contacts with teachers. In other words, in this model, background characteristics interact with institutional factors influencing student satisfaction with the university. Numerous studies have demonstrated the positive effects of student-university interaction on persistence (Cox & Orehovec, 2007; Pascarella & Terenzini, 2005; Braxton, Shaw Sullivan, & Johnson, 1997). Event history modelling is another model much discussed in literature: proposed by Des Jardins, Albourg and Mccallan (DesJardins, Ahlburg, & McCall, 1999), this model takes into account the role of the succession of different events in the different stages of the student's educational career, changing the importance of factors from year to year, depending on the time period.

In all these models, the relationship between students and institutions is relevant to reduce dropout rates (Cabrera, Castaneda, Nora, & Hengstler, 1992) and several strategies have been identified to improve student retention (Larsen, 2013; Siri, 2015).

From numerous U.S. research (Camara & Echternacht, 2000; S. Hu & Kuh, 2002; Kuncel, Hezlett, & Ones, 2004; Bridgeman, McCamley-Jenkins, & Ervin, 2000; Kuncel & Hezlett, 2007; Kuncel, Crede, & Thomas, 2007), the baccalaureate grade proved to be the best predictor of the performance of the first academic year (predicting better than the standardized SAT scores) and more specifically of the average grade that the student obtains at the first year of college (Perfetto, 2002). However, the link between the maturity grade and persistence in the educational system remains a controversial topic: Rosenbaum (Rosenbaum, 2004, p.2) asserts that "the predictor of the probability that a student will graduate easier to use is still his grade of maturity"; likewise Ishitani (2006, p. 18) states that "the ranking position in the class at maturity has significant effects on the behavior of university attrition". At the same time, however, other literature researches consider the maturity grade and the scores for standardized tests (e.g. SAT) insufficient to predict persistence at university (Ting & Robinson, 1998; Lohfink & Paulsen, 2005).

In Italy, due to the very high dropout rates in higher education (ANVUR, 2018), several specific studies were conducted (Burgalassi, Biasi, Capobianco, & Moretti, 2016; Moretti, Burgalassi, & Giuliani, 2017; Carbone & Piras, 1998) which confirmed the value of the baccalaureate vote (and of the entry skills of students more generally) together with the socio-demographic traits of the students (mostly the socio-economic context) as valid predictors of university dropout compared to the outcome of the first year of study.

Many of the models and studies carried out, both national and international, presented different analyses from the psychological point of view, building psychological-motivational models focused on expectation, reasons for involvement, personal value and motivation in general (Bandura, 1997; Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Marshall & Brown, 2004; Weiner, 1985; Gifford, Briceno-Perriott, & Mianzo, 2006; Covington, 2000; Pintrich, 2000). These models and surveys all involve the collection of data by interviewing students directly, through the use of tools (usually questionnaires) specially administered. The study presented in this article, however, aims to use only the data available in any university statistical office, without, therefore, at least at this stage of research, interviewing students directly. In this regard, it was decided to proceed to the analysis of these data through the use of Artificial Intelligence (AI).

Also literature show the use of different types of data analysis methodologies: correlational analysis (Araque, Roldan, & Salguero, 2009; Gutierrez et al., 2015; Bernardo Gutirrez, Esteban Garca, Gonzlez Garca, Nez Prez, & Dobarro Gonzlez, 2017; Willcoxson, 2010), univariate or multivariate variance analysis (Cukusic, Garaca, & Jadric, 2014), logistic regression and structural equations (Duque, Duque, & Suriach, 2013; Ghignoni, 2017; Santelices, Cataln, Kruger, & Horn, 2016), and multi-level analysis (Georg, 2009). The crucial issue with these statistic methodologies is the statistical requirements (i.e. data normality) and the difficulty of interpretation.

Today, AI and Machine Learning (ML) in general is used to replace human activities that are repetitive, for example, in the field of autonomous driving or for the task of classifying images. In these areas, AI competes with the man with quite satisfactory results and, in the case of abandonment of the educational system, it is extremely unlikely that an experienced teacher will be able to "predict" the educational success of the student based on data provided by the administrative offices.

ML and statistical techniques have in common the main focus of learning the underlying phenomena through the analysis of previously generated data. However, they use two completely different approaches: ML algorithms need some requirements to be fulfilled but usually they are free from most of the statistical assumptions (i.e. a linear regression assumes a linear relationship between an independent and a dependent variable, independence of observations and homoscedasticity).

There are different approaches in ML: KNN and other lazy methods (Altman, 1992), tree construction-based methods (i.e. C4.5) (Quinlan, 2014), classification and regression trees (Breiman, 2001), Neural of Bayesian networks (Mitchell, 1997). The present study aims to learn about underlying phenomena of dropout of the full cohort of students in the Roma Tre University in Italy (R3U) by using ML-based methods to predict the phenomenon before it happens so to identify attrition paths and to prevent students' dropout by taking appropriate measures. The main aim of this study is to define a Convolutional Neural Networks (CNN) model (a particular type of Neural Networks (NN)) that can be used in other universities, defining and predicting dropout students' characteristics. We propose the following research hypotheses (RH):

- RH1 By using CNN it will be possible to predict student dropout for an entire cohort of students using only personal and non-academic characteristics
- RH2 By using CNN it will be possible to predict student dropout for an entire cohort of students on different degree courses using also academic characteristics

The recent advances on NN, made by using CNN, have been disruptive in the field of the AI. By stacking tens or hundreds of convolutional neural layers together, one gets a deep network structure, which has proven very effective in producing high precision models. These advances have shown that AI may be able to compete (or even exceed) with human capabilities in the tasks of classification and recognition.

The paper is organized as follows. In Section 2, are reported some of the most important studies on the use of AI for the prediction of university dropout. In Section 3, we briefly summarize the CNNs and Bayesian networks and we describe our custom CNN model. Then the metrics for the evaluation of these models are presented. Furthermore, it is described in detail a case study at Roma Tre University. In Section 4, we give some discussions on the methodology and on the results of the case study. Finally, in Section 5, conclusions on the study are briefly drawn.

2. Related literature

In this section, we discuss previous works that investigated the university dropout using Educational Data Mining techniques (EDM) (Bala and Ojha, 2012, Koedinger et al., 2015).

From the analysis of the literature it emerged that the algorithm of Decision Tree (DT) is the most commonly used for developing predictive models whose aim is to identify university dropout (Alban et al., 2019). A research conducted at the University of Chittagong examined the possibility of predicting university dropout using models based on the CART (Classification And Regression Tree) and CHAID (Chi-squared Automatic Interaction Detector) with the cross-validation folder to decide which model is more efficient than other in terms of accuracy (Mustafa et al., 2012). An Indian research has evaluated the models developed by DT algorithm using accuracy, precision, recall and F1 measure (Sivakumar et al., 2016). Another research project has implemented DT using socio-economic, academic and institutional data (Pereira et al., 2013).

In addition to DT, other classification methods were used in order to implement models for predicting university dropout. A research conducted at the University of Genoa used NN to detect students at risk of dropout (Siri, 2015). Another example is the work done at the College of Technology in Mato Grosso. The research presents a model developed with Fuzzy-ARTMAP Neural Network using only the enrolment data collected for seven-year period and the results show a success rate of accuracy over 85% (Martinho et al., 2013). In another study at Budapest University of Technology and Economics, 6 types of algorithms were employed to identify students at risk of dropout using the data of 15,285 university students (Nagy and Molontay, 2018).

The studies mentioned above use different data, algorithms, performance, metrics and methodologies therefore it is impossible to say which one is better than other due to heterogeneity. On the other hand, all the studies confirm the effectiveness of data mining approach to analyze and predict university dropout as highlighted by the work of Alban and Mauricio (Alban et al., 2019). As far as we are concerned (Agrusti et al., 2019, Mezzini et al. 2019), the difference from our approach and the above-mentioned studies is that we have used CNNs to analyze educational data.

3. Methods

The main aim of the research is to predict, as early as possible, which student will dropout in the HE context. In this research we want to investigate the use of deep learning and artificial neural networks for predicting the dropout of a student from HE. We further compare the results, obtained using the deep learning approach, with a more classical method which use Bayesian Networks.

3.1 Classification

One of the most important problem of the field of AI is the *classification problem* (LeCun et al., 2015). In the classification problem we have objects which can be images, sounds or written sentences and we want to associate to each object a class taken from a finite set K of predefined classes. If we represent each object as an n-dimensional vector of real numbers $\boldsymbol{x} \in \mathbb{R}^n$, the solution of the classification problem consists in finding a function $f : \mathbb{R}^n \rightarrow K$ that associates to each object $\boldsymbol{x}$ its class. We refer to $f(\boldsymbol{x})$ as the *true class* of $\boldsymbol{x}$.

3.1.1 Neural Networks

A NN can be viewed as a function ϕ that takes as input an n-dimensional vector $\boldsymbol{x}$ and produces a value, called *prediction* on $\boldsymbol{x}$. The prediction is *correct* when $\phi(\boldsymbol{x}) = f(\boldsymbol{x})$ and *incorrect* otherwise. Contrary to the classical process of algorithm design, in which the designer, in order to build the algorithm for solving a problem, needs a complete and thorough understanding of the nature of the problem to solve, (like for example in (Mezzini, 2018, Mezzini and Moscarini, 2016, Mezzini, 2016, Mezzini and Moscarini, 2015, Mezzini, 2012, Malvestuto et al., 2011, Mezzini, 2011, Mezzini and Moscarini, 2010, Mezzini, 2010, Mezzini, 2007)) in order to implement a NN, for the solution of a problem, the programmer can even be completely unaware of the mechanism or the semantic of the classification. For having a NN to produce correct predictions, we need that the NN undergo to a *training process*. The training process consists of feeding the NN with a set of objects, called the *training set*, and denoted as $T = (\boldsymbol{x}_i, f(\boldsymbol{x}_i)), i = 1, \dots, N$ where N is the number of elements of the training sets. The class $f(\boldsymbol{x}_i)$, of each object $\boldsymbol{x}_i$ in the training set, is already known. This part of the training process is called the *forward pass*.

For each object $\boldsymbol{x}_i$ in the training set, the value $f(\boldsymbol{x}_i)$ is compared to the prediction $\phi(\boldsymbol{x}_i)$ of the NN. If the value of the prediction $\phi(\boldsymbol{x}_i)$ is different from its class $f(\boldsymbol{x}_i)$, the NN will be modified according to some optimization rule (Qian, 1999), in order to correct the error. Among different types of NN the CNN have gained much popularity since recently when cutting edge breakthrough have been obtained in the image classification task (Krizhevsky et al., 2012).

We employed three different architectures of CNN in order to test their effectiveness for our predictive model. The first two architectures, called respectively ResNetV2 (RNV2) (He et al., 2016) and InceptionResNetV4 (IRNV4) (Szegedy et al., 2017) represent the state of the art of CNN and perform the best or among the best (at the date of 2017) against industrial benchmarks. The third architecture, called DFSV1, was built by us by making modifications to the ResNet (He et al., 2016) and VGG architectures (Bengio and LeCun, 2015).

3.1.2 Bayesian Networks

Bayesian Networks (BN) are one of the most effective tool for the classification task (Pearl, 1988). Let $\boldsymbol{U} = \{A_1, \dots, A_n\}$ be a set of discrete random variables. We call the set of all the possible different values the variable A_i can take, the *domain* of A_i. A BN describes a joint probability distribution of the set of random variables over $\boldsymbol{U}$ both qualitatively and quantitatively by using a directed acyclic graph (DAG) and a set of parameters. Formally a BN $\mathcal{B} = (G, \Theta)$ where G is a DAG whose vertex set is $\boldsymbol{U}$ and Θ contains the parameters of the network in the form $\Theta = \{\theta_A | A \in \boldsymbol{U}\}$ where $\theta_A = P(A|\Pi_A)$ where Π_A is the set of parents of A in G and $P(A|\Pi_A)$ represent the probability distribution of A given its parents Π_A. Based on this, we can decompose the joint probability distribution as

$$P(\boldsymbol{U}) = \prod_{A \in \boldsymbol{U}} P(A|\Pi_A)$$

For conducting all our tests with the BN we used the R package and the BN learning algorithms contained in *bnlearn* library (Scutari, 2010).

3.2 Model evaluation

Performance's evaluation of classification model is mainly based on the count of cases correctly and incorrectly classified.

Here we consider the case in which there are only two classes, labeled respectively $+1$ and -1.We represent the number of correctly and incorrectly classified cases in the *confusion matrix* (CM). On the CM the rows represent the real classes and the columns represent the predicted classes.

On a cell $(i,j), i,j \in \{-1,+1\}$ of the CM we put the number of cases predicted as *j* by the model but having real label *i* (see Table 1).

		Predicted	Class
		−1	+1
Real Class	−1	*TN*	*FP*
	+1	*FN*	*TP*

Table 1 - Confusion matrix of a binary classification problem.

Therefore, in the case of a binary classification problem, the CM is composed of four different values: true negatives (TN), false positives (FP), false negatives (FN) and true positives (TP) as reported in Table 1.

We use the CM to build several useful metrics in order to evaluate the performance of a classification model. The first metric to consider is the *Accuracy* that measures the ability of the classification model to provide reliable predictions on new data:

$$\text{accuracy} = \frac{\text{TP} + \text{TN}}{\text{FP} + \text{FN} + \text{TP} + \text{TN}}$$

When the number of real positive cases is much greater than the number of real false cases (or viceversa) the *accuracy* could be a misleading measure of the effectiveness of the model. Therefore, other evaluation metrics such as *precision* and *recall* are used. Specifically, *precision* is the proportion between true positives and all values classified as positive:

$$precision = \frac{TP}{TP + FP}$$

The higher the value of *precision*, the lower the number of FPs. On the other hand, the *recall* measure is the proportion between the true positives and all the values that are actually positive:

$$recall = \frac{TP}{TP + FN}$$

The *recall* describes how efficient is the model in recognizing the observed property. Furthermore, there is another metric that can be used to evaluate a classification model and it is called F_1 *measure*. This metric represents harmonic average between *recall* and

$$F_1 measure = \frac{2|TP|}{2|TP| + |FP| + |FN|}$$

The F_1 *measure* is useful for evaluating the model when *recall* and *precision* are equally important (Tan et al., 2005).

3.3 A case study at Roma Tre University

We collected, from the administration office of Roma Tre University, a dataset of students enrolled in the Department of Education (DE). The years of enrollment ranges from 2009 up to 2014 comprising a total of 6078 students. We found that 649 of all students were still active at the time when we acquired the dataset (August 2018), while the remaining 5429 closed the course of their studies either because they graduated or because they dropped out or by other reasons, explained later. We refer to this set of students as the *no active* students. Note that in the following when we will refer to the *enrollment year* (or simply the year) of a student we mean the number of years passed since her/his first enrollment to university, that is, we refer to an integer value between 0 and 9 since no student is enrolled for more than 9 years.

List 1	List 2
Year of beginning of studies	Academic year
Year of birth	Course code
Gender	Course name
Country of birth	Course year
High school type	Family income class
High school exit score	Working status
High school maximum exit score	Exemption from taxes
Year ending high school	Type of exemption from taxes
Transferred from other university	Handicap
ECTS from other university	Part time status
Faculty	Part time ECTS
	Type of renew of enrollment

Table 2 - List of administrative attributes.

3.3.1 Database construction

In general, each of the no active student is classified in two different classes: *Graduated* and *Dropout*. We excluded later all students which do not classified in these two classes, like for example students who changed faculty within the R3U or went to another university. The number of such students is 118. The number of graduated students is 2833 while the number of who dropped out is 2478.

We obtained, from the R3U's administrative office, most of the (out of what were available) administrative fields of all students. In the Table 2 is reported the list of administrative fields that are used.

Note that, for a given student, the value of the attributes in List 2 of Table 2, may change during her/his academic career from year to year, while the value of attributes in List 1 does not change during all her/his academic career.

List 3
Exam name
Score of the exam
Maximum score of the exam
ECTS of the exam
Exam date (month/day)
Academic year
Type of validation

Table 3 - List of the attributes relative to student's career.

The attributes in List 3 of Table 3 are relative to the student's academic career. They represent the attributes relative to each test or exam given by the student. Note that the field "ECTS of the exam" refer to the European Credit Transfer and Accumulation System.

In order to construct the training set all the domains of the dataset are converted, using an arbitrary bijective function, to a non-negative integer domain. For example, the domain of the attribute GENDER, was converted to the domain $\{0,1\}$ where 0 correspond to "male" and 1 to "female".

We created a table STUDENT, whose schema *S* contains all the attributes in List 1 of Table 2. For each field of List 2, we added to *S*, four fields, denoted as f_y where $y = 0,\ldots,3$, that is, one field for each of the first 3 year of enrollment to the university. We limited our tests only to the students that are still active at the year 3 because after that year the number of those students dropping out to university is very small and not significant from statistical and/or practical purposes. If a student ends his/her career in the year z, $0 \leq z < y$, then f_y will take the value δ for every year $z < y \leq 3$. The value of δ, which was arbitrarily chosen to be equal to -1, can be considered as a NULL value and it does not appear in the original domain of any field on the scheme *S*. Furthermore, for any field in the List 3 of Table 3 and for each year of enrollment $y \in \{1, 2, 3\}$ an integer m_y is set to represent the maximum number of exams sustained by any student on the year of enrollment y. We found that $m_1 = 24$, $m_2 = 19$ and $m_2 = 23$. Thus, for any field in List 3, for each year y and for each $z, 0 \leq z \leq m_y$, we added a field denoted as $g_{y,z}$. If a student in the year $y > 0$ of her/his academic career completes successfully no more than j exams, then the value of the field $g_{y,z}$ is set to δ for each $j < z \leq m_y$. Overall the table STUDENT has 530 fields (although we collected data up to year 5 totaling 897 fields).

			Validation								Test							
Year	T.	Arch.	Dropout		Degree		Acc.	Prec.	Recall	F1	Dropout		Degree		Acc.	Prec.	Recall	F1
			True	False	True	False					True	False	True	False				
0	B	RNV2	166	105	111	50	64,12%	61,25%	76,85%	68,17%	144	138	121	38	60,09%	51,06%	79,12%	62,07%
0	B	INCRV4	183	120	96	33	64,58%	60,40%	84,72%	70,52%	151	155	104	31	57,82%	49,35%	82,97%	61,89%
0	B	DFSV1	160	96	132	43	67,75%	62,50%	78,82%	69,72%	159	116	113	54	61,54%	57,82%	74,65%	65,16%
1	A	RNV2	65	10	228	20	90,71%	86,67%	76,47%	81,25%	44	16	199	37	82,09%	73,33%	54,32%	62,41%
1	A	INCRV4	67	17	221	18	89,16%	79,76%	78,82%	79,29%	50	23	192	31	81,76%	68,49%	61,73%	64,94%
1	A	DFSV1	65	22	216	20	87,00%	74,71%	76,47%	75,58%	52	26	189	29	81,42%	66,67%	64,20%	65,41%
1	B	RNV2	47	43	186	40	73,73%	52,22%	54,02%	53,11%	33	33	205	52	73,68%	50,00%	38,82%	43,71%
1	B	INCRV4	60	74	155	27	68,04%	44,78%	68,97%	54,30%	52	76	162	33	66,25%	40,63%	61,18%	48,83%
1	B	DFSV1	62	94	143	24	63,47%	39,74%	72,09%	51,24%	51	87	141	24	63,37%	36,96%	68,00%	47,89%
1	C	RNV2	61	23	215	24	85,45%	72,62%	71,76%	72,19%	44	25	190	37	79,05%	63,77%	54,32%	58,67%
1	C	INCRV4	54	24	233	17	87,50%	69,23%	76,06%	72,48%	42	34	195	43	75,48%	55,26%	49,41%	52,17%
1	C	DFSV1	54	28	229	17	86,28%	65,85%	76,06%	70,59%	45	30	199	40	77,71%	60,00%	52,94%	56,25%
2	A	RNV2	35	6	228	15	92,61%	85,37%	70,00%	76,92%	15	6	221	21	89,73%	71,43%	41,67%	52,63%
2	A	INCRV4	38	13	221	12	91,20%	74,51%	76,00%	75,25%	17	8	219	19	89,73%	68,00%	47,22%	55,74%
2	A	DFSV1	33	6	228	17	91,90%	84,62%	66,00%	74,16%	14	4	223	22	90,11%	77,78%	38,89%	51,85%
2	B	RNV2	16	9	243	15	91,52%	64,00%	51,61%	57,14%	11	14	213	41	80,29%	44,00%	21,15%	28,57%
2	B	INCRV4	15	5	247	16	92,58%	75,00%	48,39%	58,82%	12	13	214	40	81,00%	48,00%	23,08%	31,17%
2	B	DFSV1	17	10	242	14	91,52%	62,96%	54,84%	58,62%	15	21	206	37	79,21%	41,67%	28,85%	34,09%
2	C	RNV2	29	7	211	16	91,25%	80,56%	64,44%	71,60%	17	15	237	14	89,75%	53,13%	54,84%	53,97%
2	C	INCRV4	32	14	201	13	89,62%	69,57%	71,11%	70,33%	22	23	235	18	86,24%	48,89%	55,00%	51,76%
2	C	DFSV1	30	10	205	15	90,38%	75,00%	66,67%	70,59%	25	18	240	15	88,93%	58,14%	62,50%	60,24%
3	A	RNV2	19	3	94	6	92,62%	86,36%	76,00%	80,85%	13	11	91	10	83,20%	54,17%	56,52%	55,32%
3	A	INCRV4	19	1	96	6	94,26%	95,00%	76,00%	84,44%	13	4	98	10	88,80%	76,47%	56,52%	65,00%
3	A	DFSV1	20	3	94	5	93,44%	86,96%	80,00%	83,33%	12	3	99	11	88,80%	80,00%	52,17%	63,16%
3	B	RNV2	14	6	91	11	86,07%	70,00%	56,00%	62,22%	7	8	94	16	80,80%	46,67%	30,43%	36,84%
3	B	INCRV4	14	4	93	11	87,70%	77,78%	56,00%	65,12%	1	4	98	22	79,20%	20,00%	4,35%	7,14%
3	B	DFSV1	16	8	89	9	86,07%	66,67%	64,00%	65,31%	5	10	92	18	77,60%	33,33%	21,74%	26,32%
3	C	RNV2	17	3	94	8	90,98%	85,00%	68,00%	75,56%	11	5	97	12	86,40%	68,75%	47,83%	56,41%
3	C	INCRV4	18	6	106	4	92,54%	75,00%	81,82%	78,26%	19	8	105	14	84,93%	70,37%	57,58%	63,33%
3	C	DFSV1	17	2	95	8	91,80%	89,47%	68,00%	77,27%	12	5	97	11	87,20%	70,59%	52,17%	60,00%

Table 4 - Here we report the confusion matrix for the epochs with the best F_1 measure on the validation set. The confusion matrix for the test set was computed using the very same model that achieved the best F_1 measure on the validation set. Column 'T' stands for table type (A, B or C).

We build a table called Y_LABEL containing two attributes: STUDENTID and DROPOUT, where the last represents the label of each student. It has a numerical domain with the following meanings:

$$\text{DROPOUT} = \begin{cases} 0, & \text{if the student graduated} \\ 1, & \text{if the student dropped out} \end{cases}$$

From the table STUDENT described above, we derived three type of tables denoted as STUDENT_A$_x$, STUDENT_B$_x$ and STUDENT_C$_x$ for $0 \leq x \leq 3$ where x is the number of years from the first enrollment.

In the schema of tables STUDENT_A$_x$ we added all the attributes in List 1 and all the attributes in List 2 (of the type f_y), and all the attributes of List 3 (of type $g_{y,z}$) for all $y = 0,\ldots,x$.

The tables denoted as STUDENT_B$_x$, $x = 0,\ldots,3$, contain only the attributes of List 1 and List 2. That is, we considered in these tables only administrative fields and we excluded the fields related to the academic careers of the students (the ones of type $g_{y,z}$).

The tables STUDENT_C$_x$, $x = 0,\ldots,3$ have been constructed in the following way. We computed, for each student, the following aggregate statistics: DIFFYEAR and for each year $x > 0$, NUMBEREXAMS$_X$, AVGSCORE$_X$ and SUMETCS$_X$. The first statistic contains the value

YEAR OF BIRTH − YEAR OF BEGINNING OF STUDIES − 19

that is, the difference in years between the age of the student (at the date of the enrollment) and 19. The other statistics contains, for each student and for each year $x = 1,2,3$ respectively, the number of exams successfully passed, the average score of the exams successfully passed and the sum of the ECTS gained. We thus obtained the schema of STUDENT_C$_x$ by adding to the schema of each table STUDENT_B$_x$, all the above four fields. The idea we want to test here is whether it is better and effective to use only some significant aggregate statistics or, instead, it is better and effective to use all the attributes relative to the academic career (like in tables STUDENT_A$_x$).

For the tests of both CNN and BN we choose a random permutation of all no active students. Next, we partitioned all students in twelve different mutually disjoint groups containing approximately 450 students each thus obtaining a partition $\mathcal{P} = \{P_0, P_1, \ldots, P_{11}\}$. For all $0 \leq i \leq 11$ the group P_i is used as a validation set V_i and the group $P_{i+1\ mod\ 12}$ as a test set T_i and the students in the remaining groups, as the training set A_i.

In the validation set for the year x we put only the students who, at that year of enrollment, were still active.

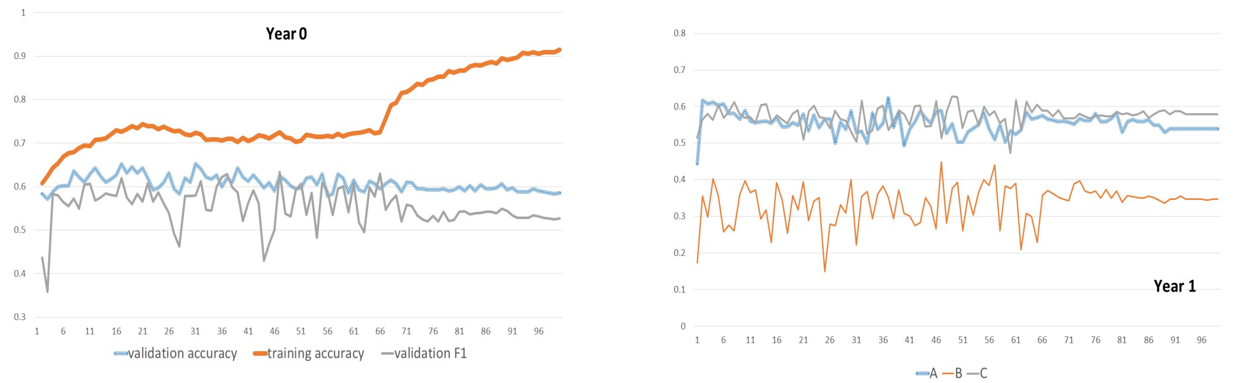

Figure 1 - On the left. Accuracy of the training of data taken from table STUDENT_B₀ for the validation set, the training set and the F_1 measure for the validation set. Students of the validation set are taken from the partition group 0. On the right. The F_1 measure for the validation set, year 1, partition group 0 and for the three different tables STUDENT_A$_X$, STUDENT_B$_X$ and STUDENT_C$_X$. For both figures the horizontal axis is the number of epochs.

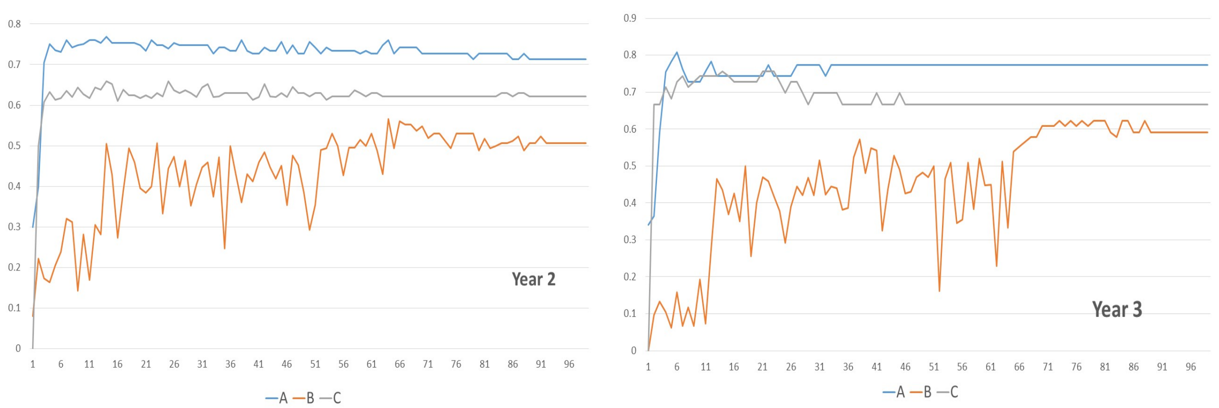

Figure 2 - The F_1 measure for the validation set, partition group 0 and for the three different tables STUDENT_A$_X$, STUDENT_B$_X$ and STUDENT_C$_X$. On the left. Year 2. On the right. Year 3. For both figures the horizontal axis is the number of epochs

3.3.2 CNN Training experiments and data

We trained three models based on the CNN architectures mentioned above by taking from each of the table above (A or B or C) the training, validation and test sets from the partition $\mathcal{P}$.

We got data from a total of 43200 epochs. For each epoch the confusion matrix of both the validation and the test sets were produced.

We found that the F_1 measure, was the better indicator for the selection of the best model.

In Figure 1 and Figure 2 we report the graph relative to the training of the model RNV2 for 100 epochs. In the graph on the left of Figure 1 we report the accuracy for the validation set, for the training set and the F_1 measure. Training and validation data where taken from the table STUDENT_B$_0$. In the graph on the right of Figure 1 and in the graphs of Figure 2 we report the value of the F_1 measure for the year 1 (Figure 1 on the right) and for the years 2 and 3 (Figure 2) for the three different tables STUDENT_A$_X$, STUDENT_B$_X$ and STUDENT_C$_X$. We observe that in all three cases the value of the F_1 measure relative at the table STUDENT_B$_X$ is always worse in every year. This clearly shows that using only administrative data gives very poor performance in predicting the dropout of a student. In Table 4 we report the data of the confusion matrix, for both validation and test sets, in which the validation set, among the twelve possible different sets of the partition $\mathcal{P}$, achieved the best score on the F_1measure.

3.3.3 Bayesian Networks training experiments and data

In order to compare the results and better understand the quality of the data produced by the CNN models, we executed extensive tests using BN on the same dataset. We used the *bnlearn* library available for the R package. In the bnlearn library there are several algorithms, for learning the BN from data, which are divided in three classes: (i) structural based learning, (ii) score-based learning and (iii) mixed structural and score-based learning. Furthermore, it has two classifiers, based on naive Bayes and tree Bayes (Friedman et al., 1997). In all the cases we used the default hyperparameters or default score functions for learning the model.

Year	Type	Algorithm	Validation								Test							
			Dropout		Degree		Accuracy	Precision	Recall	F1	Dropout		Degree		Accuracy	Precision	Recall	F1
			True	False	True	False					True	False	True	False				
0	B	14	118	45	171	98	66,90%	72,39%	54,63%	62,27%	102	67	192	80	66,67%	60,36%	56,04%	58,12%
1	A	9, 10	64	17	221	21	88,24%	79,01%	75,29%	77,11%	45	16	199	36	82,43%	73,77%	55,56%	63,38%
1	B	15	38	48	177	46	69,58%	44,19%	45,24%	44,71%	28	40	194	56	69,81%	41,18%	33,33%	36,84%
1	C	3, 5, 6, 9, 12	64	17	221	21	88,24%	79,01%	75,29%	77,11%	45	16	199	36	82,43%	73,77%	55,56%	63,38%
2	A	9, 10	35	13	220	15	90,11%	72,92%	70,00%	71,43%	18	15	212	18	87,45%	54,55%	50,00%	52,17%
2	B	2, 8, 9, 10, 13	37	19	215	13	88,73%	66,07%	74,00%	69,81%	20	22	205	16	85,55%	47,62%	55,56%	51,28%
2	C	5, 9, 10	32	9	225	18	90,49%	78,05%	64,00%	70,33%	17	2	225	18	92,37%	89,47%	48,57%	62,96%
3	A	9, 10	18	4	98	5	92,80%	81,82%	78,26%	80,00%	17	11	92	7	85,83%	60,71%	70,83%	65,38%
3	B	6,12	13	0	90	12	89,57%	100,00%	52,00%	68,42%	4	6	95	14	83,19%	40,00%	22,22%	28,57%
3	C	5, 9, 10	19	6	87	3	92,17%	76,00%	86,36%	80,85%	23	7	94	10	87,31%	76,67%	69,70%	73,02%

Table 5 - The confusion matrix for the BN models with the best F_1 measure among all different twelve groups.

We compute the predictions both on the test and the validation set and, following the same methodology used with the CNN, we considered only those models that give the best F_1 measure. The results are presented in Table 5. In the column "Algorithm" we reported the id of either the algorithm or the classifier that give the best result on the F_1 measure.

When there is more than one id this means that all the algorithms gave exactly the same results.

4. Discussions and Conclusions

We explored the effectiveness of predicting the dropout from university using three different sets of features. The first one, containing all the academic and administrative features (tables STUDENT_A_X). The second one, containing only administrative features (tables STUDENT_B_X) and the third (tables STUDENT_C_X) containing the administrative features and 3 aggregate statistics about the academic career of the students. The experiment showed that using only administrative features does not give good results and the models using only them are always outperformed by models using also the academic career features or aggregate statistics.

Furthermore, the models using, besides administrative features, also aggregate statistics perform slightly worse than the models using only and all the academic careers features. From all the above discussion we clearly conclude that the more accurate data we have the more precise and effective the model's predictions could be. The experiments done also demonstrated that using CNNs give us better results than using the BNs.

We implemented several state-of-the-art CNNs models, using real data of students of the DE in the R3U enrolled between 2009 and 2014. We also developed several BN models for predicting the university dropout. We compared the experiments made with CNNs with the one using the BNs. Much works could be also developed in the future. First, we can incorporate in the data the fields not included due to privacy censoring. We tested only three different architectures, but many other different CNN architectures exist in literature (Hu et al., 2018). Furthermore, many of the parameters of these architecture could be modified, and much could be explored in order to increase the effectiveness of the models.

Since it is not required that the prediction process is made in real time, we can train hundreds of models and make multiple prediction in order to reduce the random variation found in the early phase of training. Clearly the system can be made finer by introducing a prediction model every semester or even every trimester or it can be extended to other faculty or other types of students.

Acknowledgements

Research group is composed by the authors of the contribution that was edited in the following order: Mauro Mezzini (sections 3-4 excluding subsection 3.2), Gianmarco Bonavolontà (sections 2 and subsection 3.2), Francesco Agrusti (section 1).

We wish to thank the Statistical Office of R3U for the support they give us by producing all the data that were used in this research.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 55-64

Improving Elementary School's Critical Thinking Skills through Three Different PBL-Assisted Learning Media Viewed from Learning Styles

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(submitted: 30/11/2019; accepted: 13/04/2020; published: 30/04/2020)

Abstract

This research aims to analyze (1) the differences in critical thinking skills among students who were given three different PBL-assisted learning media; (2) the differences of critical thinking skills among visual and auditory students; and (3) the interaction between the three different learning media with learning styles on students' critical thinking skills. This research is a quasi-experiment with a pretest-posttest non-equivalent control-group design. The population in this research is the fifth-grade students of the elementary school in Jebres Sub-district, Surakarta, Indonesia. The sampling technique used is cluster random sampling obtaining 96 students in three experimental classes at different schools. The data of critical thinking skills are gained from test scores. The data analysis technique used is descriptive quantitative statistics through ANCOVA test with the 3 x 2 factorial design. The results of the research revealed that there are different skills in critical thinking in different learning media. The highest skills in critical thinking are reached by students who were given differentiated problem-based learning (PBL) with multimedia in their learning. There are also differences in critical thinking skills between visual and auditory students.

KEYWORDS: Critical Thinking Skills, Problem-based Learning, Multimedia, Learning Style

DOI
https://doi.org/10.20368/1971-8829/1135193

CITE AS
Laksmi E. W. F., Sarwanto, Chumdari, (2020), Improving Elementary School's Critical Thinking Skills through Three Different PBL-Assisted Learning Media. Journal of E-Learning and Knowledge Society, 16(1), 55-64.
https://doi.org/10.20368/1971-8829/1135193

1. Introduction

The Ministry of Education and Culture of the Republic of Indonesia has made various efforts in improving 21st century skills, including the implementation of the 2013 curriculum.

According to the Minister of Education and Culture Regulation number 57 of 2014, the 2013 curriculum for elementary schools contains learning skills and content in a theme that refers to the spiritual, social, knowledge, and skill core competencies (Rumahlatu et al., 2016). The 2013 curriculum is an integrated thematic learning that develops learning content into one theme and is integrated starting from the background, subject characteristics, core and basic competencies, learning design and model, assessment, media, learning resources, and the teacher's role in learning (Farisi, 2013). This is in line with Dewantara's opinion (2020) which states that thematic learning is mixed learning that uses themes to connect several subjects related to the aim of providing meaningful experiences for students. Thematic learning integrates attitudes, skills and knowledge by using themes that contain holistic learning material and is focused on everyday life (Narti et al., 2016).

The 2013 curriculum requires students to be able to master technological developments and emphasize the importance of 21st century skills. Critical thinking skills are one of the most important life skills for humans in the 21st century. These skills are considered as the main key to achieve goals for a new knowledge-based economy (Jones & Pimdee, 2017; Changwong et al., 2018). Thinking skills describe not only the ability to think according to the rules of logic and possibility, but also the ability to make decisions or solve problems in real life and society (Zulmaulida et al., 2018; Murawski, 2014; Karakoc, 2016).

Critical thinking is a process for analyzing, assessing, and evaluating arguments, claims, and evidence with deductive and inductive reasonings in order to solve a problem, decide, or make a conclusion (Halpern, 2003; and Facione, 2015). Furthermore, critical thinking is the ability to be open-minded by sorting information, formulating hypotheses, analyzing, synthesizing, and evaluating basic evidence correctly (Changwong et al., 2018; Karakoc, 2016).

Paul & Elder (2008) state the characteristics of critical thinkers as being able to ask important questions and problems, gather and assess relevant information, conclude and find reasonable solutions, being open-minded with alternative thinking systems (many possibilities), and communicating effectively with others so that they are able to solve complex problems. The indicators of critical thinking skills according to Ennis (1993) include (1) formulating the main problems, (2) revealing facts, (3) choosing logical arguments, (4) analyzing the problem from a different perspective, and (5) drawing conclusions. The indicators of critical thinking skills proposed by Facione (2015), namely interpretation, analysis, inference, evaluation, explanation, and self-regulation, are used in this research.

Learning in schools should be able to develop students' critical thinking skills. Strategies, approaches, models or methods, and learning media that facilitate the process of transferring information, generating student activity and describing problems in daily life must be used in learning.

Ideal learning to develop students' critical thinking skills is learning that provides controversial ideas, authentic problems or issues that are familiar to be solved (Ruggiero, 2012; Murawski, 2014). This causes individuals to be active and skilled in conceptualizing, applying, analyzing, synthesizing, and evaluating information to get the answer or conclusion (Costa & Kallick, 2014).

Problem based learning (PBL) is a learning model that is suitable for building students' new knowledge through investigation of solutions to problems as well as meaningful and self-motivating learning (Lambros, 2004). Barrows (1986) defines the concept of problem-based learning that was coined around 1996 as student-centered learning and the effort in developing problem-solving skills based on real-life problems provided by the teacher as a facilitator by emphasizing contextual and cognitive learning. The skills acquired by students through problem-based learning are problem-solving skills, critical thinking skills, teamwork and the skills to work independently (Barrows & Tamblyn, 1980).

This is in line with the opinion of Baysal (2017) and Boud & Feletti (1997) stating that problem-based learning is a learning model that actively engages students in authentic problem solving from real life, develops various student skills such as communication, problem solving, and critical thinking, and increases learning collaboration and motivation.

The following are the 7 stages of the PBL learning model adapted from Barrows & Wee Keng Neo (2010): (1) orientation, (2) encountering the problem, (3) tackling the learning issues, (4) reiterating and reassessing the problem, (5) summarizing and knowledge abstraction, (6) evaluating groups, and (7) evaluating tutors. Lambros (2002) states that collaboration in groups is a PBL element needed in solving problems through the form of peer support, recognition and reinforcement of knowledge, assistance of others in synthesizing new information in order to build activities that are of interest to students.

The application of the PBL model will be more effective if combined with a variety of supporting learning media. This research compares the use of modules, picture media, and multimedia assisted by the PBL model. Modules are learning materials that are arranged systematically in a language that is easily understood and positively influences students' cognitive and affective skills according to their characteristics (Dimopoulos et al., 2009; Lohfink et al., 2014). Handayani (2018) concludes that the problem-based learning module is effective in significantly increasing students' cognitive and psychomotor learning outcomes. In addition, the module is considered effective in facilitating visual learning. It can improve reflective abilities, learning achievements, and science process skills of the students (Alias, 2012; Martiningsih et al., 2019).

Furthermore, picture media are not only part of the teaching strategy but are part of the students' learning experiences through two-dimensional representations of various objects such as places, objects, people, activities, events etc. (Shabiralyani et al., 2015; Dewan, 2015). Pictures are considered better than just concrete words because they can present the intended object. Jamal and colleagues (2019), Inel & Balim (2013) and Balim and colleagues (2016) conclude that there is a positive effect of the use of comic-picture or cartoon-concept media on the problem-based learning process, including improving students' creative and critical thinking skills, improving learning outcomes, and making learning interesting and enjoyable for students.

Furthermore, multimedia is a combination of various types of digital media such as texts, images, audio, and video into an interactive verbal information application or presentation with the aim that messages or learning materials can be optimally accepted by students who have different modalities (Molina et al., 2018; Jastaniyah & Bach, 2017; Arkorful & Abaidoo, 2014). Several researches have shown that the use of PBL-based multimedia can improve students' critical thinking skills (Neo & Neo, 2001; Nirbita et al., 2018; Hussin, et al., 2019).

In addition to the application of learning models and instructional media, teachers must also consider the characteristics of students which would affect the course of the learning process. One of the characteristics of students that influences the effective use of instructional media is learning style. Not all learning styles are suitable with the application of certain learning media, and vice versa, not all learning media can facilitate all students' modalities. This is in line with the opinion of Gokalp (2013) that learning styles affect students' abilities in the learning process. Moffyza & Heong (2014) and Myers & Dyer (2006) define learning styles as characteristics of an individual's tendency to adopt strategies in receiving, collecting, organizing, and processing information in the learning process. DePorter and collegues (2007), known as an expert in the development of the learning method based on learning styles, suggest three types of learning styles, including (1) visual, (2) auditory, and (3) kinesthetic styles. This research compares students' skills with visual and auditory learning styles.

Several previous researches have analyzed the effect of learning media on students' critical thinking skills (Nirbita et al., 2018; Twiningsih et al., 2019) and the effect of learning styles on students' critical thinking skills. However, there is no research that analyzes the effect of three different learning media assisted by the PBL model and their relations to learning styles on students' critical thinking skills. Based on the background above, this research aims to (1) the differences in critical thinking skills among students who were given three different PBL-assisted learning media; (2) the differences of critical thinking skills among visual and auditory students; and (3) the interaction between the three different learning media with learning styles on students' critical thinking skills.

2. Materials and Methods

This research is a quantitative research of a quasi-experimental type. A quasi experiment is a form of experimental research where individuals have been assigned to groups randomly so that the researcher used classes with this condition as an experimental group (Creswell, 2012). The main purpose of this experimental research is to investigate the possible cause and effect by applying treatments to the experimental group I (module), II (pictures), and III (multimedia), and then comparing the results of these treatments.

This research uses a pretest-posttest non-equivalent control-group design with the 3 x 2 factorial design. The non-equivalent control-group design was chosen because this research provided treatments to groups that are comparable in terms of academic achievement, curriculum, and school facilities and are selected through random sampling (Oakes & Feldman, 2001). The pretest-posttest design was used to compare the experimental groups and measure the level of change that occurred as a result of the treatment (Bonate, 2000).

The independent variables of this research include PBL-assisted learning media, consisting of multimedia, picture media, and modules, and learning styles, consisting of visual and kinesthetic learning styles. The independent variable in this research is critical thinking skills. The 3 x 2 factorial design can be seen in Table 1.

Learning Styles (B)		Learning Media (A)		
		PBL Module (A_1)	PBL Picture (A_2)	PBL Multimedia (A_3)
	Visual (B_1)	B_1 A_1	B_1 A_2	B_1 A_3
	Auditory (B_2)	B_2 A_1	B_2 A_2	B_2 A_3

Table 1 - Factorial design 3 x 2.

The population in this research included all fifth-grade students of elementary schools in Jebres District, Surakarta, Indonesia.

The sampling technique used was cluster random sampling. This technique was chosen because the population does not consist of individuals but rather groups of individuals or classes (Alvi, 2016). The stages of implementing random cluster sampling include selecting elementary schools according to the criteria of implementing the 2013 curriculum, having comparable achievements, and having fairly complete facilities and Then using a lottery in the form of rolls of paper, on which the name of each elementary school is written, the researcher determined the module, picture, and the multimedia classes.

There were 96 sample students in this research, consisting of 31 experimental-class-I students, 34 experimental-class-II students, and 31 experimental-class-III students. Furthermore, there were 58 visual students and 27 auditory students. The fifth grade of SDN Gulon is a control class taught with PBL-assisted modules. The experimental class consisted of the fifth grade of SDN Tugu Jebres taught with PBL-assisted picture media, and the fifth grade of SDN Sabrang Lor taught PBL-assisted multimedia.

This research was conducted from August to October 2019 in elementary schools which implemented the 2013 curriculum with thematic learning. The learning materials in this research include Theme 1: Animal and Human Motion Organs (consisting of Subtheme 1, Animal Motion Organs, Subtheme 2 Animals, Humans, and Environment, and Subtheme 3 Environment and Its Benefits) and Theme 2 Clean Air for Health (consisting of Subtheme 1: How the Body Processes Clean Air, Subtheme 2 The Importance of Clean Air for Respiration, and Subtheme 3 Maintaining Human Respiratory Organs).

The instrument used to measure students' critical thinking skills was 8 open-ended questions that were in accordance with the indicators of critical thinking skills proposed by Facione (2015). These open-ended questions were assessed with a score range of 0-5. The learning style questionnaire instrument by DePorter and colleagues (2007) was used to classify students' learning styles.

The instrument was tested for its validity and reliability first. The validity test was divided into two, content validity and empirical tests. The content validity test was performed by testing the instrument to the expert. The face and format of the instrument were tested by the educational evaluation expert, the grammar was tested by the linguist, the suitability of the instrument with the level of development of child psychology was tested by the child psychologist, and the suitability and accuracy of the instrument with indicators of critical thinking skills were tested by the expert of critical thinking skills. The empirical validity of the instrument was measured using a statistical correlation analysis technique with the Product Moment test. The instrument's reliability was tested using the Conbrach Alpha's test. The hypothesis prerequisite tests consist of the normality test using Kormogolov Smirnov's test and the homogeneity test using the Levene's test. The hypotheses were tested using the covariate analysis (ANCOVA) test.

3. Results

The hypothesis tested in this study were: (1) there is a difference between students' critical thinking skills who were given three different PBL-assisted learning media; (2) there is a difference between visual and auditory critical thinking skills; (3) there is an interaction between the three different learning media with learning styles on students' critical thinking skills. The data of critical thinking skills were obtained from the results of the students' pretest and posttest. The data prerequisite tests were done through the normality test with Kolmogorov-Smirnov's One-Sample Test and the homogeneity test with Levene's Test of Equality of Error Variances. Normality test was conducted to find out whether the sample obtained is from a normally distributed population or not. A summary of the results of the normality test can be seen in Table 2.

Group of Data	N	Normality Test		Conclusion
		p-value	Sig.	
Pretest	96	0,197	0,05	Normal
Posttest	96	0,252	0,05	Normal

Table 2 - The summary of the normality test results.

Based on Table 2, it can be concluded that the data of critical thinking skills are normally distributed because p-value > sig. 0.05. After the data were declared as normally distributed, the next step was the homogeneity test. The homogeneity test was used to determine whether the sample comes from a homogeneous population or not. The summary of homogeneity test results can be seen in Table 3.

Levene Statistic	df_1	df_2	p-value	Sig.	Conclusion
1,832	1	168	0,178	0,05	Homogen

Table 3 - The summary of the homogeneity test results.

The homogeneity test results in Table 3 produce p-value > sig. 0.05. Thus, we can conclude that the data variance comes from a homogeneous population.

After the data had been proven to be normally distributed and consist of homogeneous variance, the next step was the ANCOVA test. Hypothesis testing in this research used the two-way Anova formula with 3 x 2 factorial design. The purpose of this analysis is to examine the effect of independent variables on the dependent variable. The hypothesis test decision is determined by criteria: if the p-value < 0.05, then the null hypothesis (H_o) is rejected or (H_1) is accepted. The results of the ANCOVA analysis regarding the effect of the research variables can be seen in Table 4.

Source	df	Mean Square	F	Sig.	Conclusion
Pretest	2	1711,028	7,427	0,001	H_0 accepted
Learning media	2	2794,284	10,079	0,000	H_0 accepted
Learning Styles	1	2881,707	10,395	0,002	H_0 accepted
Learning media* learning style	3	3077,201	11,100	0, 000	H_0 accepted

Table 4 - The summary of Ancova results.

Based on Table 4, it can be seen that there are difference students' critical thinking skills based on Sig. pretest 0.000 < 0.05. The hypothesis test decision 1 is H_o is rejected or H_1 is accepted because the p-value of 0.000 < 0.05. Therefore, the use of three different learning media have an effect on critical thinking skills. This can be interpreted that there are differences in students' critical thinking skills taught with PBL-assisted modules, picture media, and multimedia. Furthermore, the hypothesis 2 test decision in Table 4 is H_o is rejected or H_1 is accepted because the p-value of 0.002 < 0.05. We can conclude that learning styles have an effect on critical thinking skills. This means that there are differences in critical thinking skills between visual and auditory students. Finally, the decision of hypothesis 2 in Table 4 is H_o is rejected or H_1 accepted because the p-value of 0.000 < 0.05. It means that there is an interaction between the use of three different learning media with learning styles on critical thinking skills.

The results of the hypothesis 1 test can be illustrated in a comparison diagram of the percentage of students' frequency with the increased scores of pretest and posttest in each class presented in Figure 1.

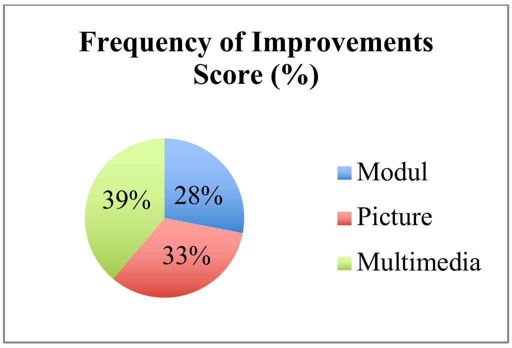

Figure 1 - Frequency of improvements scores.

To follow up on the results of the hypothesis 2 test, it is necessary to do a Least Significance Difference (LSD), which can be seen in Table 5.

Learning Media	Pretest	Posttest	Difference	Improve (%)
Modul with Visual	60,35	62,24	1,89	3,13
Modul with Auditori	35,61	41,48	5,87	16,48
Picture with Visual	61,63	68,07	6,44	10,45
Picture with Auditori	56,07	59,13	3,06	5,46
Multimedia with Visual	69,86	82,81	12,95	18,54
Multimedia with Auditori	60,63	67,75	7,12	11,74

Table 5 - The comparison of mean score of skills for all classes viewed from their learning styles.

Based on the comparative data on the average scores of students' critical thinking skills in Table 5, it can be concluded that learning styles affect students' critical thinking skills. This is because in every type of learning media, visual students always have higher critical thinking skills than auditory students. In addition, it was found that the use of multimedia in students with visual learning styles contributed the most in improving their critical thinking skills compared to the use of other learning media based on learning styles.

Furthermore, to follow up on the results of the hypothesis 3 test, a size effect test was conducted for the post hoc test, which is presented in Table 6.

Learning Media	Eta squared (n^2)	Effect size
Learning Media	0,199	Low
Learning Styles	0,114	Low
Learning Media*Gender	0,291	Medium

Table 6 - The calculation result of size effect test for Ancova test.

The effect size can be seen using eta squared and partial eta squared. This research uses partial eta squared as it presents a better effect size than eta squared (Field, 2009). Cohen (2003) divides the effect size into three categories of low (≤ 0.20), medium (≤ 0.50), and high (≤ 0.80). Based on Table 6, it can be concluded that learning media and learning styles have a weak effect on students' critical thinking skills. On the other hand, the interaction between the use of learning media and learning styles has a medium effect on students' critical thinking skills.

4. Discussion and Conclusions

Based on the research conducted, the decision of the first hypothesis test states that the null hypothesis is accepted, it can be concluded that there are different scores of critical thinking skills with different learning media. Based on the comparison diagram of the percentage of students with an increased pretest-posttest scores in each class, PBL-assisted multimedia provides the highest contribution to improve critical thinking skills by 39%, followed by the picture media by 33%, and modules by 28%.

Modules have the least contribution in improving critical thinking skills. This is due to the characteristics of elementary-school students who are at a concrete operational stage, which means their ability is to think about real objects or events (Lourenco, 2016). The module used in this research contains texts of learning materials without representation of information in the form of images, tables, or charts. This causes the module to be less able to concretize the learning material that will make the students difficult to understand abstract things more deeply. Therefore, Sejpal (2013) and Powell and colleagues (2015) state that modules are more suitable for students with more mature critical thinking skills, that is, is the student above elementary school with more developed thinking skills to understand the module without the help of representation of images, charts, diagrams, tables, etc.

The module will be more effective when combined with illustrations that can provide more explanation, extra information, interpret the broader context, and help students to remember more easily. This is supported by the research of Levie and Lentz (2015) showing that 98% of 155 students improve their understanding as a result of the effects of using illustrated modules. In this research, the picture media has a better contribution compared to modules in improving critical thinking skills. In his research, Dewan (2015) concludes that the use of picture media is better than the use of concrete words in learning. This is in line with the opinion of Shabiralyani (2015) that the use of visual media such as pictures makes the process of absorbing information in the learning process more effective. This is supported by the theory of Baker (2015) which states that the picture media makes it easier not only to recognize and process but also to remember and understand than words. Appiah (2006) also states that pictures are more effective in terms of telling something than modules or texts, in addition to that they can also be more attractive to people who need information than modules.

Multimedia provides the highest contribution compared to other learning media in improving critical thinking skills. Molina and colleagues (2018) states that multimedia is a combination of various types of digital media such as texts, images, audio and video into the application or presentation of verbal and non-verbal information that is interactive for the audience. The use of multimedia in elementary-school learning is very important because the various features of multimedia can assist teachers in transferring learning materials in an interesting and fun way so that children can understand the topic of learning easily (Jastaniyah & Bach, 2017; Arkorful & Abaidoo, 2014).

The results of this research are supported by those of Hammadi's research (2010), which concludes that the class taught using multimedia is more critical than the control class taught without multimedia. Fajari (2020) also puts forward that students taught with PBL-based multimedia obtain higher scores of critical thinking skills than the students in the control class. Furthermore, Sari and Sugiyarto (2015) conclude that there is a positive effect of the use of problem-based multimedia on critical thinking skills since students who learn to use problem-based multimedia have the ability to deduce and express better assumptions compared to those in the control class. Neo and Neo (2001) also state that learning using problem-based multimedia is more effective for improving critical thinking skills than problem-based learning without learning media.

The decision of the second hypothesis test states that there are differences in critical thinking skills between visual and auditory students. Visual students have higher critical thinking-skill scores than auditory students. This research uses modules, picture media, and multimedia assisted for the treatment. All the three learning media can facilitate students with visual learning styles. Picture media and multimedia dominate the visual elements in their appearance, while the module is full of sentences. Meanwhile, auditory students are only facilitated by audio in multimedia. Thus, visual students benefit more from the three different learning media compared to auditory students. This is why, the average score of visual students' critical thinking skills is higher than that of auditory students' critical thinking skills. This is in line with the research of Gilakjani (2012) who concludes that multimedia is more suitable for visual students than auditory students, so that visual students have better academic performance. Facilitation of students with visual learning styles will have an impact on the optimal absorption of materials from the learning media compared to less-facilitated learning styles. The optimal absorption of learning contents is the basis for developing students' critical thinking skills. This is supported by the opinion of Gokalp (2013) that learning styles affect students' abilities in the learning process.

The result of this hypothesis test is consistent with the research hypothesis which states that visual students have higher critical thinking skills than auditory students. Suliman (2006) in his research also concludes that there is a correlation between learning styles and different levels of students' critical thinking skills (low, medium, and high). The results of this research are also supported by Nosratinia and Soleimannejad (2016) concluding that there is an effect of learning styles on students' critical thinking skills. However, the results of this research contradict those of Myers and Dyer's (2006) which show no difference in students' critical thinking skills based on their learning styles and those of Dilekli's (2017) which state that there are no significant differences between the variables of learning styles and critical thinking skills. Thus, we can imply that there is no effect of learning styles on students' critical thinking skills.

The third hypothesis test states that there is an interaction between the use of the three different learning media and learning styles on critical thinking skills. In other words, there are differences in students' critical thinking skills viewed from the experimental class and their learning styles. Based on the effect size test, PBL-based multimedia applied to visual students provides the highest contribution in improving critical thinking skills when compared to the effect of other learning media and learning styles. If you look at the average scores of students' critical thinking skills, there are different scores on visual students and auditory students. In each experimental class, visual students always have higher scores compared to auditory students. This is supported by the research results of Smith and Woody (2000) that multimedia is very beneficial for students with high visual orientation. Lu and Yang (2018) also conclude that students with visual learning styles get better learning achievements than those with other styles that are equally taught by multimedia.

Meanwhile, the use of modules in visual students contributes the lowest to improve critical thinking skills. The use of modules in this research is considered less effective for visual students because they are not motivated to learn just by only seeing texts without information representations such as tables, charts, or other informative images. Students who are not motivated in learning will not try to achieve learning goals to the maximum. This is supported by the opinion of Souriyavongsa and colleagues (2013) about the factors that cause the low learning activities of students i.e. students' interest in the presentation of learning materials.

The results of this research are backed by the research of Wanpen (2013) and Rahadian and Budiningsih (2017) who conclude that there is an interaction between learning media and learning styles in influencing the ability to understand learning materials that has an impact on the students' achievements. Smith and Woody (2000) and Surjono (2015) also conclude that there is an interaction between learning media and learning styles on the achievements of student learning performance. Soylu and Akkoyunlu (2002) and Fan and Xiao (2015) in their research also conclude that there is an interaction between learning media and learning styles on students' learning outcomes.

Based on the results of the research and discussion, we can conclude that the three PBL-assisted learning media have an effect on students' critical thinking skills. Students with multimedia have the highest critical thinking skills. Furthermore, learning styles have an effect on students' critical thinking skills. Visual students have higher critical thinking skills compared to auditory students. Based on the results of the effect size test, there is an interaction between the three PBL-assisted media and the learning styles on students' critical thinking skills. PBL-assisted multimedia contributes the highest in improving students' critical thinking skills.

Based on the above conclusions, there are some recommendations for teachers to apply PBL-assisted multimedia to the learning process in elementary schools to train students' critical thinking skills. This is because PBL-based multimedia provides the highest contribution in improving critical thinking skills (especially for visual students) when compared to the effect of other learning media and learning styles. In addition, the teacher has to adjust the making of multimedia to all types of students' learning styles such as the addition of audio elements so that auditory students are properly facilitated. On the other hand, the use of modules that are too intense in learning is very ineffective for elementary school students. Critical thinking skills must be trained from an early age because these skills are the 21st century life skills that are the most important for students' lives in the future. Furthermore, students' critical thinking skills must be routinely trained through meaningful learning and thinking habits as early as possible.

This research is limited to the elementary-school level. It would be far more interesting to do the research in the middle or high school students who have more mature thinking skills. In addition, future researchers can conduct similar researches by measuring other 21st century skills such as creative-thinking skills, problem-solving skills, communication skills and so on.

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 65-71

Technology to enable new paradigms of teaching/learning in mathematics: the digital interactive storytelling case

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(submitted: 15/12/2019; accepted: 20/04/2020; published: 30/04/2020)

Abstract

This paper concerns the design and implementation of a particular methodology for mathematics teaching/learning which exploits an interactive and immersive metaphor of storytelling. This research aims to promote processes such as inquiring, conjecturing, formalizing, proving in mathematics, and to investigate which is the best way to organize ICT tools to achieve that purpose. We also report the findings of an ongoing experimentation at the K12 school level.

KEYWORDS: Digital Storytelling, Mathematics Education, Collaborative Learning, Moodle.

DOI
https://doi.org/10.20368/1971-8829/1135201

CITE AS
Albano G., Coppola C., Dello Iacono U., Fiorentino G., Pierri A., Polo M., (2020), Technology to enable new paradigms of teaching/learning in mathematics: the digital interactive storytelling case. Journal of E-Learning and Knowledge Society, 16(1), 65-71. https://doi.org/10.20368/1971-8829/1135201

1. Introduction

This study concerns the PRIN project "Digital Interactive Storytelling in Mathematics: a competence-based social approach", aimed to define a socio-constructivist methodology to build didactic activities within a competence-oriented mathematics education framework, named DIST-M (Digital Interactive Storytelling in Mathematics) (Albano & Dello Iacono, 2018). More specifically, the objectives of the project are:

- to improve the DIST-M methodology by means of more adaptive collaborative scripts, able to better support social interaction within online group(s) and useful for more personalized path, with respect to the roles that students play during the tasks;
- to amplify the reach of peer-tutoring, providing more efficient tools to support students with difficulties;
- to use suitable tools to perform Social Network Analysis to evaluate the organization in cohesive aggregation by means of algorithms for detecting communities (Polo, Dello Iacono, Fiorentino & Pierri, 2019).

The approach is based on the use of collaborative scripts (King, 2007; Kobb et al., 2007) within a sequence of Vygotskian tasks (Vygotsky, 1980) embedded in a digital storytelling framework. The methodology provides for interaction among peers on an e-learning platform (Moodle) (Albano, Dello Iacono & Fiorentino, 2016) integrated in a suitable way with other kinds of semiotic mediators, especially suitable for mathematics learning.

This paper is focused on the design and implementation aspects of DIST-M, paying attention to the role of (inter)mediation of the platform. We investigate how to exploit a platform to design learning activities embedded in storytelling context aimed to support the development of students' argumentative capabilities in mathematics.

Here we present the theoretical framework and the starting point for the implementation of the collaborative scripts. Then we move to the technological features. Finally, we draw some conclusions from the experimentations in the classes.

2. Theoretical framework

We refer mainly to two theoretical frameworks in mathematics education literature: the discursive approach to the teaching and learning of mathematics (Sfard, 2001) and the story problems (Zan, 2012).

According to Sfard, thinking is a case of communication and languages are not only carriers of pre-existing meanings, but they are constructors of the meanings themselves. Learning becomes the participation to a discourse, that is the "mathematical discourse". In our case, the discourse takes place in a mainly written communication, since it develops in digital platforms. This could appear as a constraint, instead it should be assumed as a strong point. Indeed, in accordance with Radford (2002), writing is considered as a semiotic tool for objectification, used from individuals in the social processes of production of meanings, to gain a stable kind of awareness, to make explicit and visible own thoughts and to accomplish actions.

The story problems are those in which the mathematical structure is embedded into a familiar situation for the student and takes the shape of a narrative. To understand the story, the student has to resort not only to logical thinking, which is the one that deals with explaining what happens in a deductive logic, but also to narrative thinking, which is the one making sense of things, dealing with intentions, desires, beliefs and feelings (Bruner, 1986).

In order to allow the story to support the problem-solving process, the narrative and logical dimensions should be well combined (Zan, 2012). Zan emphasizes that the issue should naturally arise from the need to achieve a purpose and the student should imagine that his resolution activity can influence the story.

The collaborative and Vygotskian approach, based on social and individual construction of knowledge, supports the development of argumentative and communicative skills (Lazarou, Sutherland & Erduran, 2016). Students, engaged in the activities planned by the scripts, analyse and explain their reasonings, conjecturing arguing and interacting with their classmates in order to persuade them of the validity of their argumentations and to take into account those of the others. In order to improve the collaborative learning experience, we adapted the scripts to individual and group characteristics, carrying out adaptive collaboration scripts (Baker, 2003), which are very effective in promoting a better self-regulation of learning (Demetriadis & Karakostas, 2008), especially in online environments (Azevedo et al., 2005).

3. The case study

From a mathematical point of view, DIST-M aims to support the development of students' abilities in algebraic modelling, in producing conjectures, argumentations and proofs. The mathematical task that students face is:

> "*Choose four consecutive natural numbers, multiply the two intermediate numbers, multiply the two extremes, and subtract the results. What do you get?" (Mellone & Tortora, 2015).*

The problem is embedded in a story and given in a narrative way (Liljedahl, & Zazkis 2009; Zan, 2012).

As the narrative progresses, the story evolves according to the characters' interaction with it. The genre chosen was science fiction, which sees a group of four friends engaged in the task of communicating with aliens from whom they had received mysterious messages made up of numbers and operations.

Four friends correspond within the story to four characters following described:

- *Marco*, the BOSS, leader of his group of friends, and has obtained with his ways of doing, the trust of his companions.
- *Sofia*, reading lover, enjoys writing, wants to be a journalist and has the obsession of the blog. In fact, they call her the BLOGGER.
- *Clara* has a diffident personality and often torments her companions with doubts and questions...she's a real PEST.
- *Federico*, computer lover, is convinced of the existence of extra-terrestrial and he is always looking for creative and brilliant ideas to share with friends; for this reason, he is named PROMOTER.

The four students of the group will agree among themselves within Chat tool their role in the story, considering the aspects of their personality.

Alongside the four friends, there is also an adult, Gianmaria, Federico's uncle, also an expert in computer devices and a lover of mathematics. Gianmaria (the GURU in the story) is the teacher/tutor's avatar and acts as an expert in the learning process.

The story problem starts from Federico who, fascinated by life beyond the planet Earth, has developed an electronic device in the hope of capturing some signal from the space. And finally, one day, a sequence of characters appears on the screen.

Unfortunately, during reception the device breaks down and the message remains incomplete. Federico's curiosity is too strong that he involves his friends in this adventure, looking for the meaning of those signs and a way to communicate with the aliens.

To get help in the task, the four friends decide to involve Gianmaria, who agrees to help them solve the enigma.

The interactions among them and with Gianmaria guide the flow of the story (and of the learning path), and lead them to continue communicating with the aliens, after Federico has fixed the device and also connected it with the smartphones of each of them.

This new feature allows aliens to send a different message to each of them, so that in a second phase the group is called to think about different sequences and find out what they have in common (in the case of consecutive odd and even numbers, which lead to 8).

The story has been divided into episodes, so you can add or choose to enjoy an indefinite number of episodes. Each episode gives space for new questions.

4. Design of DIST-M

All the learning activities take place in the context of a narrative, an engaging and familiar situation for the student. The genre chosen was that of science fiction, which sees a group of four friends working in the enterprise of communicating with aliens from whom they had received mysterious messages made up of numbers and arithmetic operations. In addition to the four friends, there is also an adult, who is the teacher/tutor's avatar and acts as an expert in the learning process. Each student is a character of the story (Liljedahl, 2007; Albano, Pierri & Polo, 2019) and the personal and group interactions are moderated by the teacher through the character assumed in the story. The story evolves over time following the characters' interactions with it.
The whole activity of DIST-M consists of different tasks, as shown in Figure 1.

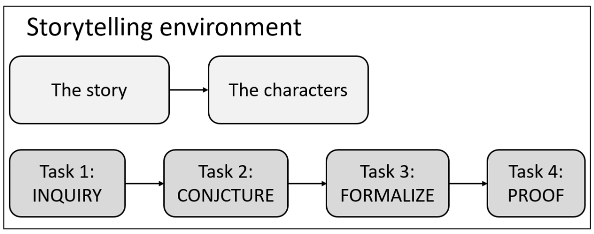


Figure 1 - The tasks.

The students are embedded in a storytelling environment, consisting in comics strips. The story and its characters are firstly introduced. Then the students are engaged in four tasks, which develop according to the story, as described below:

- *Task 1 - Inquiry*: the students, starting from their observations, produce a description of what has been observed.
- *Task 2 - Conjecture:* the description obtained is rearranged to produce conjecture in verbal language.
- *Task 3 - Formalize:* the students formalize the conjecture produced to prepare the way for the proof.
- *Task 4 - Proof:* here the students must construct the proof and to justify each step of the deduction.

Students are divided into Characters and Onlookers. Characters assume the roles of Boss, Blogger, Pest, and Promoter (see Section 3). In each episode, the group of Characters plays as the protagonist while the Onlookers, also divided into groups, observe the Characters during the carrying out of the task. Each onlooker observes a specific role. Roles, both Characters and Onlookers, are exchanged in each episode, so that each student plays a different role, as a character or as an onlooker, to internalize them (Vygotsky, 1980). Each task provides for some moments of individual work and some others of collaborative work and discussion with the expert. The expert acts as mediator intervening as necessary in informal moments of work among peers (using the chat) and in moments explicitly reserved to the debate (in the forum). Moreover, the expert has a favourite communication channel with the Promoter, to start the problem-solving phase or if in impasse. Her role of mediator regards both the mathematics and the communication.

5. Implementation and role of technology

The theoretical framework described in the previous sections guided the design of the DIST-M and its implementation for a case study. In this section we provide a brief description of how this was done using an online learning environment.

The implementation of complex learning activities as the those described so far requires a sophisticated and flexible environment like Moodle. In fact, all activities and (social) interactions planned in the DIST-M were implemented with Moodle, choosing and fine-tuning the most suitable tool for each didactic and communicative task.

The implementation considered all the main aspects of the design: the narrative setting, the small group approach, the importance of communications as a way to foster argumentative skills, the metacognitive reflection.

We choose the best Moodle tool for each communication activity according to the expected linguistic register. So, for instance, we used Chats to handle all immediate and informal discussions between the characters and for private messaging between the Promoter and the Guru. On the contrary, we used Forums to manage all formal discussions between characters and the Guru, promoting the transition towards more literate registers (Ferrari, 2004).

We used Moodle groups to partition students into teams of 5 member/characters: Boss, Promoter, Blogger and two Pests. Each group was isolated from the others using Moodle's separated group mode (which gives the illusion of a separate course for each group, virtualizing the activities of one course), this allows students to work in small groups while granting the Guru (with a suitably configured Moodle role) the privileges to monitor all activities and step in when invoked or necessary.

A specially crafted Moodle role was used to implement the onlookers, which can see all discussions between characters in Chats and Forums but are not authorized to participate. Moreover, onlookers belonging to the same group can communicate with each other by means of dedicated Chats whose visibility and access permission is restricted by checking their special role.

The narrative approach has been fully supported by some customizations that allowed us to design the entire user experience of the student as if he were inside a comic book. In fact, each episode of the story is implemented with a Moodle Book resource whose pages are filled with using comics created with the online environment Toondoo and Microsoft PowerPoint. Furthermore, the whole learning environment looks like a comic strip, thanks to some labels/comics used as links to stealth activities (available but hidden in the homepage of the course). A few lines of custom CSS allowed to adapt to this immediate and unconventional layout almost all the other activities and resources.

Several parallel didactic paths were built, foreseen by the instructional design described in the previous sections, have been enforced using Moodle's access conditions, leveraging on the belonging to the various groups/characters of the story. For example, the private chat between Promoter and Guru is visible only to the former; the Questionnaire simulating the emailing is only visible to Bloggers; the dedicated Onlookers Chat is visible only to them.

Finally, many Moodle tools have been expanded integrating or embedding digital applications such as interactive GeoGebra constructions Albano & Dello Iacono, 2019a). Their availability, however, can be chosen by the Guru, according to the needs and mood of the discussion.

More in detail, three GeoGebra applications have been created and embedded within Moodle activities:

- a (GeoGebra) spreadsheet (view) is embedded to support the students during the inquiry (task 1); it allows to play with the quadruples, insert new ones, and quickly test relationships on all of them (Figure 2);
- two Interactive Semi-open Questions (ISQ) (Albano & Dello Iacono, 2019b) to support the conjecture production (task 2) and the formalization (task 3) respectively. These that allow the assembly of mathematical statements (sentences) by dragging digital tiles (words) (Figure 3). We chose the digital tiles in such a way as to make available to the students the main keywords, numbers, letters, causal conjunctions, symbols, and mathematical expressions. The aim is to allow the student to produce verbal conjectures and statements, in a formalized mathematical language. We also added tiles to allow the composition of sentences revealing the most common errors.

Figure 2 - GeoGebra spreadsheet [Image text translation: "to insert a formula, you have to start with an = sign, as shown in the example below"].

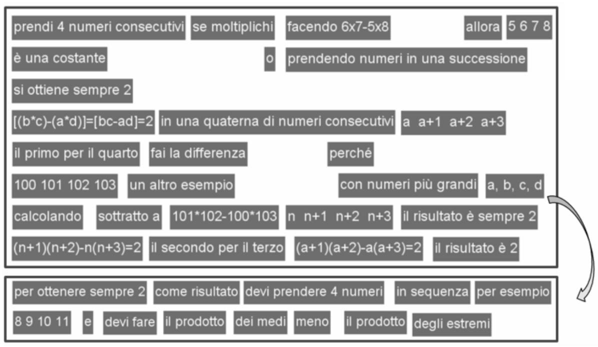


Figure 3 - Interactive Semi-open Question (ISQ) [Image text translation: "to always get 2 - as the result - take 4 numbers - in a row - for instance 8 9 10 11 - and - compute - the product - of the intermediate terms - minus - the product - of the extreme terms"].

6. Sample from experimentation

In this work, we show the significant aspects of an experimentation involving three teachers and around 60 students from three different classes from first and second year of high school. The teachers and the respective classes are from three different places.

During the experiments, the teacher's training interventions and their typologies, the management problems and the involvement/participation of the students and their difficulties were investigated. The first results show that the immersive aspect of storytelling, together with collaborative work and online interactions, typical of platform activities, can lead to a change in students' attitudes towards mathematics and their relationship with the teacher.

In this paper we want to give a taste of what happened, focusing on the Conjecture phase. The Figure 4 shows the starting point of the problematic situation to be faced by the students. They received some strings of symbols, reported by Federico on a piece of paper, and they tried to understand them.

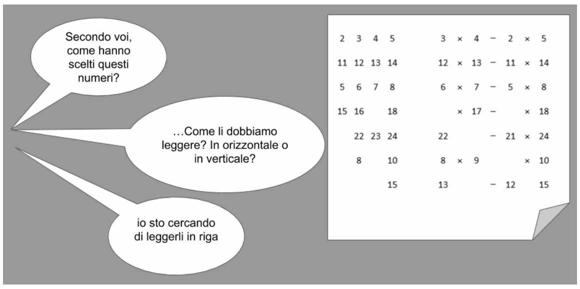


Figure 4 - The problematic situation [Image text translation: "How do you think they chose the numbers?" "Should we read them horizontally or vertically?" "I'm trying to consider them line by line"].

Each line of the paper shows a sequence of four consecutive numbers, followed by their combination under suitable operations. Some lines lack some information (see white spaces). This want to focus the students' attention to two facts: the consecutiveness of the given number, and the order of the operations with respect to the number sequence.

At beginning the students explore the problematic situation, looking at the data on the sheet and maybe making some trials with new number sequences. The exploration should bring them to make a conjecture, at beginning in form of a verbal statement.

The following scene 1C shows a debate among peers, while they are conjecturing.

Excerpt 1 - Scene 1C:

Pest: *therefore, in a series of consecutive numbers, if we make the difference between the product of the first and second terms which are always consecutive and between the first and the fourth term which have 2 as difference, the result will always be* 2
Pest: *If it were done in another way would not be 2*
Boss: *Yes, for me the reasoning is really okay.*

We can note the emergence of the correct conjecture, although it is supported by a weak argument: "*If it were done in another way would not be 2*", which has been approved as a very correct reasoning from a peer. It is worthwhile to see that the collaborative mood during the peers' interaction is supported by the consistent role played by Pest and Boss.

The following scene 2C shows how sometimes there is the need of some personal reflection.

Excerpt 2 - Scene 2C:

Pest: *I still don't have clear ideas*
Boss: *guys! read [the numbers] vertically…!!!!*
Blogger: *I have read it, but I'm still trying to understand*
Promoter: *do you have any idea?*
Boss: *do you realize that going little by little they are numbers that follow one another*
Boss: *do we read and find ourselves in chat in 5 minutes?*
Promoter: *I have few ideas and confused too*
Promoter: *listen to me for a moment*
Pest: *speak*
Promoter: *2 3 4 5*
Promoter: *the 3 X 4*
Promoter: *2 X 5*
Blogger: it is 2
Blogger: *the first line of the second column*
Promoter: *that is the two extremes and the two middle ones*
Promoter: *they all do the same*
Promoter: *there are four terms and the two middle ones, and the two extremes are multiplied*
Promoter: *and then they are subtracted*

Note that all the students are engaged in producing the conjecture. Moreover, we can observe how the intervention of the Boss suggesting, in a deadlock moment, to read again and think alone for five minutes and then come back in the chat, produces the effect that the Promoter, who was the one with "*few ideas and confused too*" now is who successes in understanding which is the formula corresponding to the given sequences.

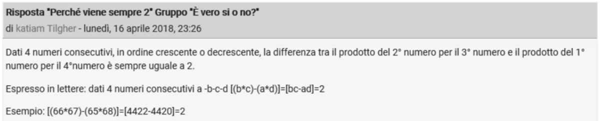
Let us conclude with the last scene showing how the students become embedded in the narration

Excerpt 3 - scene 3C:

Pest: *the various results that we derive from the various calculations could not be geographical coordinates?*
Boss: *after having reasoned with my group, we decided that aliens maybe want to tell us that maybe they are two and this explains why from the quadruplets always two comes out.*

In the following we show an excerpt from the Forum, where the students move to communicate with Gianmaria (that is the expert). After exploring and comparing with peers, once they reach a common conjecture, they propose their statement to Gianmaria (Figure 5).

The verbal statement produced by the students is correct. It is worthwhile to note that in interacting with the "expert", the production of a symbolic formulation and of an example immediately arise. The crucial point is that the symbolic expression uses the letter a,b,c,d (that refers implicitly to the consecutiveness of the numbers) is not pertinent in order to produce the proof of the conjecture. Note that the "=" in the expression "[bc-ad]=2" is imposed by the students, differently from the previous one which is correct from mathematical point of view. This is a very important issue from the didactical point of view. That is why we foresee an episode of the story dedicated to move from the verbal conjecture to a symbolic one which is suitable to be manipulated according to mathematical procedures in order to prove the given statement. Figure 6 shows a comics strip to go further to the next episode.



Risposta "Perché viene sempre 2" Gruppo "È vero si o no?"
di katiam Tilgher - lunedì, 16 aprile 2018, 23:26

Dati 4 numeri consecutivi, in ordine crescente o decrescente, la differenza tra il prodotto del 2° numero per il 3° numero e il prodotto del 1° numero per il 4°numero è sempre uguale a 2.

Espresso in lettere: dati 4 numeri consecutivi a -b-c-d [(b*c)-(a*d)]=[bc-ad]=2

Esempio: [(66*67)-(65*68)]=[4422-4420]=2

Figure 5 - An excerpt from the Forum [Image text translation: Given four consecutive numbers, in ascending or descending order, the difference between the product of the 2nd number and the 3rd number and the product of the 1st number for the 4th number is always equal to 2. In symbols given four consecutive numbers a-b-c-d [(b*c)-(a*d)] = [bc-ad] = 2 Example: [(66*67)-(65*68)] = [4422-4420] = 2].

Figure 6 - A comics strip [Image text translation: "Yes, good idea. We can say that now we understand the secret of the quadruples" - "But how do we tell them? They probably don't speak our language"].

7. Discussions and Conclusions

As the experimentations made and in progress, the narrative framework, enriched with digital semiotic mediators, seems to engage students both from the motivational point of view and mathematical one, fostering the production of conjectures and supporting them in proving them. The implementation of the different roles in the articulated collaborative tasks, the use of chats and forums, has contributed to let the students experience and, perhaps, internalize a way of being a mathematician.

During the experimentations, the students asked for more digital tiles to better formalize their conjectures. Some digital tiles were added in real time by the researcher in charge of this activity. The issue has been finally overcome modifying the ISQ to allow students to create their own digital tiles. This feature will be tested in future trails.

We started the project with the following research question in mind: "how to support the development of students' argumentative capabilities in mathematics" by means of involving and inclusive activities. We thought (and found) that technology is certainly part of the answer. In fact, we believe that rich online teaching and learning environments (such as Moodle and GeoGebra) should no longer be considered in merely instrumental terms, but as enabling technologies, without which much advanced teaching, like the one described in this work, is almost impossible to achieve. Technology can play an important role as a semiotic mediator using artifacts where mathematical knowledge is embedded and ready to be explored by students. A DIST-M can be implemented in the teaching daily practice choosing suitable problems (i.e. well integrated within the classroom curriculum) and foreseeing a final assessment. To this purpose, we are currently working on a new (evaluation) phase at the end of the story. It is also worth remarking that, after a few runs, the role should be interiorized enough to relax some of technological requirements for the activity to work.

We conclude underlying the fundamental insight that ICT can offer to the teacher. By observing communications and spontaneous connections between students the teacher can timely detect dangerous misconceptions and classroom dynamics and act consequently. In fact, they provide a sort of augmented reality whose importance will grow with the arrival of the forthcoming Learning Analytics tools.

Acknowledgements

The research is funded by the Italian Ministry of Education, University and Research under the National Project "Digital Interactive Storytelling in Mathematics: a competence-based social approach", PRIN 2015, Prot. 20155NPRA5. We acknowledge the teacher Piera Romano and her students for participating in the project experimentation..

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JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 16, No. 01 (2020), pp. 72-77

Enabling smart learning systems within smart cities using open data

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(submitted: 07/01/2020; accepted: 13/04/2020; published: 30/04/2020)

Abstract

Deploying ad-hoc learning environments to use and represent data from multiple sources and networks and to dynamically respond to user demands could be very expensive and ineffective in the long run. Moreover, most of the available data is wasted without extracting potentially useful information and knowledge because of the lack of established mechanisms and standards. It is preferable to focus on data availability to choose and develop interoperability strategies suitable for smart learning systems based on open standards and allowing seamless integration of third-party data and custom applications. This paper highlights the opportunity to take advantage of emerging technologies, like the linked open data platforms and automatic reasoning to effectively handle the vast amount of information and to use data linked queries in the domain of cognitive smart learning systems.

KEYWORDS: Smart Learning Systems, Linked Open Data, Cognitive Computing in Education

DOI
https://doi.org/ 10.20368/1971-8829/1135239

CITE AS
Carbonaro A., (2020), Enabling smart learning systems within smart cities using open data.Journal of E-Learning and Knowledge Society, 16(1), 72-77.
https://doi.org/ 10.20368/1971-8829/1135239

1. Introduction

The connection between smart learning systems and smart cities (SC) is strong. From 2010 the interest in SC began to grow exponentially. In (Harrison et al., 2010) Harrison defined a SC as an instrumented, interconnected, and intelligent city. Instrumented refers to the collection and integration of data from the use of sensors, applications, personal devices, and other resources. Interconnected refers to the integration of all such data and to the provision of a set of services. Intelligent refers to the complex elements, such as analytical calculations, modelling and visualization of services for better operational decisions. Some important technology trends are favouring the dissemination of data in SC: i) data provision from sensors that are smaller, less expensive and more reliable ii) sensors and data processing capabilities that are increasingly interconnected via the Internet of (every) Thing iii) open data innovation leading to the creation of a global data space containing billions of assertions (Lim et al., 2018). Only by making data linked and open will it be possible to integrate them and establish truly interoperable SC. The same features describe smart learning systems: available educational data can be collected and integrated in order to enhance decision-making and deliver better learning resources to the users, in particular, personalisation and inference reasoning (Andronico et al., 2004). In the context of technology-enhanced learning, such a data model could be employed to analyse information from multiple data sources, like generic or domain-specific datasets, and unify them in an interlinked data-processing area, in a Linked Open Data (LOD) approach. In this way, smart learning systems can effectively provide services by the public value it creates for users (Riccucci et al., 2007). Frequently, the intrinsic potential of the available online educational data and datasets are wasted without extracting potentially useful information and knowledge because of the lack of established mechanisms and standards (Riccucci et al., 2005). Rather, they can be exploited using sophisticated data analysis techniques such as automatic reasoning to find patterns and extract information and knowledge (Carbonaro, 2010), (Coccoli et al., 2016, 2017), (Gomede et al., 2018), (Muniasamy and Anandhavalli, 2020). Moreover, education information sharing and analysis in conjunction with non-traditional data sources (e.g., social media, web content, and linked data) can provide an important component to facilitate the development of the next generation of smart technology-enhanced learning services. However, due to the high heterogeneity of data representation and serialisation formats, and a lack of commonly accepted standards, the education landscape is characterised by the ubiquitous presence of data silos, which prevents domain experts from obtaining a consistent representation of the whole knowledge. Without a shared data model for such concept integration, it is impossible to actuate automatic data analysis processes like inference reasoning, especially within inter-domain contexts.

This paper aims to illustrate the characteristics that a framework for the integration and interoperability of data and concepts in the field of cognitive smart learning systems should have. This paper highlights the opportunity to take advantage of emerging technologies, like the LOD platforms to effectively handle the vast amount of information and to use data linked queries. One of the most important features of the linked data is their ability to enrich internal data archives with external data that could come from open data, statistics, DBpedia, Massive Open Online Courses and other LOD cloud sources. In particular, we illustrate a promising approach and an example of its application in the context of an Introduction to Algorithms and C Programming Language course taken as an example addressing the personalisation of all learning process components to different learners' characteristics. The paper is organized as follows: the next Section shows recent research efforts to apply LOD principles and technologies to solve problems around learning environments, such as the interoperability of educational data and resources, enrichment of material and recommendation and personalisation content. Section 3 describes the proposed creation of a common model interconnecting a variety of heterogeneous data sources and establish a personalized ontology-based framework, considering a C programming case study. Section 4 presents built ontologies used to formally describe the entities and relationships involved in concepts and the associated background knowledge. Section 5 shows how SPARQL and SWRL can be used to create innovative personalised-learning content systems that are connected to the SW. Finally, some considerations and conclusions close the paper.

2. Open and Connected Smart Learning Environment

LOD principles have been adopted by an increasing number of data providers over the last years, about geographic locations, people, companies, books, scientific publications, proteins, online communities, etc. Topics such as ontology building, use of semantics technologies and future applications that will be supported by these technologies are becoming important research areas in their own right (Ristoski and Paulheim, 2016). Open data has significant potential to foster innovation (Carbonaro, 2012), (Carbonaro et al., 2018) (Bizer et al., 2011)). For example, innovation and significant economic and social value can be created by using datasets such as map data, public transport timetables, statistical data and data on international trade or crime. To carry out this data opening an agreement is necessary to harmonize and organize the structure or format, data catalogues and metadata, which allow the relationships between all open databases available to be searched for and established. The interconnection of the variety of publicly available data sources can significantly facilitate reuse, exploitation, and possible extension of data.

The mEducator project (http://www.meducator.net) demonstrates how the LD principles can be applied to model and expose metadata of both educational resources and services/APIs. The metadata of educational resources, retrieved from different services, are transformed from their native formats into RDF and are made accessible via URIs (Uniform Resource Identifiers). The mEducator metadata schema covers the most frequently used aspects of educational resources from basic ones such as title and descriptions to more sophisticated ones such as learning outcomes and licensing models. The results of the experimental evaluation demonstrated improved interoperability and retrievability of the resource descriptions, presented as part of an interlinked resource graph.

Vega-Gorgojo et al. (Vega-Gorgojo et al., 2015) underline the importance of use of LD for improving the visibility of course offerings, recommendation of educational material or expert matching; the study doesn't consider personalization according to the learning styles. The authors state that LOD movement promises to improve existing practices of system integration, resource sharing and personalization to support learning.

An interesting review conducted by Pereira et al. (Pereira et al., 2018) shows efforts to apply the LOD principles and technologies to solve known problems such as interoperability of educational data and resources, access to data for various analyses, enrichment of material, and recommendation and personalization content. They obtained evidence regarding how the results of the recent researches in semantic technologies in education, more specifically the movement of LOD, are being applied in practice.

ELaCv2 (Chrysafiadi et al., 2020) is a recent integrated adaptive educational environment that provides e-training in programming and the language 'C'; the system schedules dynamically the learning material for each individual learner and proposes which domain concepts are known and unknown and which domain concepts need revision.

From the above-mentioned papers, it is possible to underline some main issues: the semantic interoperability of smart learning connected concepts and their data is crucial but still poorly widespread. Often, concepts and data are represented in a disjointed context resulting into vertical application development.

3. Source Code Semantic Annotation, Interlinking and Enrichment

This paper suggests a smart learning framework addressing the personalisation of all learning process components (learning objects, relevant learning/teaching methods and preferred learning activities) to different learners' characteristics. Let's take as an example the domain of teaching and learning to program in a specific programming language, for example, C computer programming. To identify the different elements and key concepts of the C source code, a phase of analysis of the source code is fundamental. This is usually done by creating a concrete syntax tree (CST) and an abstract syntax tree (AST). The first tree represents the syntactic structure of a string according to a certain formal grammar; parsers convert a CST into a more contextualized AST for practical use. The different elements identified by AST including arrays, pointers, functions, variables and inline documentation are then annotated according to their type. Eclipse CDT and its class and concept framework were used for the parsing and AST construction. Semantic annotation process assigns metadata to source code elements to allow subsequent processing and understanding. The semantic annotation process begins after the parser has analysed the source code to identify the different constructs. The task of semantic annotation is to annotate the elements identified with the appropriate concepts defined in the used ontology. The annotation component models the Resource Description Framework graph and adds semantic descriptions using the SE ontology. The source code elements represented in the AST are used for construct RDF statements as triples <subject, predicate, object> or <subject, predicate, literal value> to semantically describe resources (in this case, resources are the elements of learning knowledge of the source code such as class, method, parameter, parameter, return like, etc.).

Considering that the re-use of ontologies and interconnection with other relevant entities promotes the interoperability of knowledge, where possible, re-used ontologies can be adopted and used in the community to produce network effects. Within the interlinking and enrichment process, different vocabularies are used to enrich the semantic description of resources annotated by the semantic annotation component. In the context of smart learning systems, two types of datasets should be considered: (1) those directly related to educational information, containing, for example, educational resources, institutional data and educational indicators; and (2) datasets that can be used in teaching and learning scenarios, while not being directly published for this purpose, for example, datasets from different domains (libraries, encyclopedias, etc.), such as the ones made available by the Europeana project (http://www.europeana.eu/), as well as the collection of British Museum, available as LD (Piedra et al., 2015). Some of the most cited datasets are DBpedia (http://wiki.dbpedia.org/), GeoNames (http://www.geonames.org/), MusicBrainz (https://musicbrainz.org/), Bio2RDF (http://bio2rdf.org/) and PubMed (http://pubmed.bio2rdf.org/ sparql). This most cited datasets, also known as data hubs in the LOD cloud, are datasets that are interlinked with many others. Interlinked datasets with hubs are essential, mainly to make data findable and reusable. The Dublin Core (http://dublincore.org/ specifications/) is one of the simplest and most widely used metadata schema. Originally developed to describe web resources, Dublin Core has been used to describe a variety of physical and digital resources. Dublin Core is comprised of 15 core metadata elements; whereas the qualified Dublin Core set includes additional metadata elements to provide for greater specificity and granularity.

One specific vocabulary is Learning Object Metadata Ontology (a mapping of IEEE LOM - Learning Object Metadata elements to RDF based on the LD principles) (http://kmr.nada.kth.se/static/ims/md-lomrdf.html). This standard focuses specifically on the syntax and semantics of digital or non-digital learning objects.

The number of academic institutions publishing LD is constantly growing, as the growing lists of partners at the LinkedUniversties.org and LinkedEducation.org websites show. An institution publishes information about the courses it offers through its website and makes them available in RDF format, such as Open University (Qing, Dietze et al., 2012).

4. Framework Personalisation

Semantic Web describes a new way to make resources content more meaningful to machines, whereas the meaning of data is provided by the use of ontologies (Reda et al., 2018), (Patel and Jain, 2019). Ontologies, as a source of formally defined terms, play an important role within knowledge-intensive domains overcoming the problem of interpreting homonyms and synonyms in different sources. Ontologies can also be reused, shared, and integrated across applications. They provide a common agreed understanding of the domain by specifying a formal representation of the entities and relationships involved in concepts and the associated background knowledge. Some recommendations are provided on the use of ontologies: describe resources with previously defined ontologies whenever possible, extend standard ontologies and, where necessary, create ontology mappings to reconcile terms. We used these recommendations and identified the main following C programming concepts: i) the preprocessor directives, which define actions to be performed before the compilation process, ii) the functions, which can be invoked in the programs, iii) expressions, which define pieces of code that can be reduced to a value, iv) modifications applicable to declarations of functions and variables, v) declarations, understood as both declarations of functions, variables and types, but also as expressions of the program control flow, vi) data types, both primitive and user-defined and vii) the variables, understood as all the memory locations accessible from the program. So, the built ontology includes the classes and properties characteristic of a C language source code. For example, we added the Conditional Directive class, Define Directive class, and Include Directive class as subclasses of the Directive class. We added the Dereferencing Expression class and Referencing Expression class as subclasses of the Expression class. We added the Enum Type Declaration class, Struct Type Declaration class, Union Type Declaration class and Type Alias Declaration class as subclasses of the Type Declaration class. Moreover, regarding properties, we added hasFunctionDeclaration property, hasTypeDeclaration property and hasVariableDeclaration property as subproperties of the hasDeclaration property. We added the isAliasedBy property as a subproperty of the isReferencedBy property. We added pointsTo as a subproperty of the owl:topObjectProperty.

Our framework personalises the learning environment and provides learners with suitable learning objects, learning activities, and teaching methods based on their different preferences and needs. All components are explicitly and precisely represented using ontologies. We built the Learner Model Ontology to describe all characteristics related to the learner, which influence how she/he interacts with a learning system. For example, the Learner Model Ontology comprises the PersonalInformation class, Learning-Style class, BackgroundKnowledge class, and Preferences class. There are different models to represent learning styles; including the Myers-Briggs Learning Style (Extroverts, Introverts, Intuitions, Sensing, Thinking, Feeling), VAK learning style model (visual [verbal], visual [non-verbal], auditory and kinaesthetic), and the Felder Silverman Learning Style Model (Sensory/intuitive, Visual/verbal, Active/reflective, Sequential/global). The developed Learning Activities Ontology represents the variety of learning activities that help learners learn better. For example, the learning activities ontology comprises the Experiments, GroupWork, LabWork and Lecture classes. Finally, the built Learning Object Ontology consists of different Modules that introduce the learning module and its suitability for various learners at various levels. For example, the learning object ontology comprises the DifficultyLevel class, LearningObjectType class, and Structure class.

5. Inference Mechanisms in Proposed Framework

The procedure of semantic annotation is applied to C programs on the basis of the built ontologies. The source codes are extracted from the archive of the programs that the author of this paper provides to first-year computer science students within the Introduction to Algorithms and C Programming Language course offered during the first semester at the University of Bologna, Italy. Input data represented in semi-structured formats are transformed into an RDF graph and the datasets are thus semantically annotated according to reference ontologies and stored within a triple-store server. Users can interact with the system using either web-based access or the SPARQL endpoint. SPARQL endpoint promotes single standardized access and creates an inter-linked source graph. When educational institution offers SPARQL endpoint, we can reach to its data using standard schemas and link its own data with other open education linked data based on "one data, multiple applications" idea. For example, we could use a SPARQL query to navigate the linked datasets and ask for each student, the courses that deal with the topics of interest, divided by concept. Listing 1 illustrates the code snippet of the described SPARQL query.

```
SELECT ?Student ?Course ?ConceptName
(count(distinct ?Source) as ?Sources)
WHERE {
    ?Student :isInterestedIn ?Concept.
    ?Source :hasConcept ?Concept.
    ?Concept rdfs:label ?ConceptName.
    ?Source :hasLearningStyle ?Learning.
    ?Course :hasLearningObject ?Source.
    ?Student :hasLearnerProfile ?LearningM.
    ?LearningM lm:isIntuitive ?Learning.
    ?Student a ?StudentLevel.
    ?Course :isFor ?StudentLevel.}
```

```
GROUP BY ?Student ?LearningM ?Course
?ConceptName
ORDER BY ?Student ?ConceptName ?Sources
```

Listing 1 - An example SPARQL query that retrieves the names of students and courses that contain concepts in which the students are interested.

We decided to investigate the SWRL potential in our application as an essential step to formalise the logic layer for ontologies. The existence of a standardised rule language for the SW and using it with ontologies will create innovative personalised-learning content systems that are connected to the SW. For example, through the SWRL rule below, it is possible to make the reasoner deduce in a fully automatic way which are the most suitable teaching materials for the specific student, based on his learning goal and learning style. Listing 2 illustrates the code snippet of the described SWRL rule.

```
Student (?p) ^ hasLearnerProfile (?p , ?lp ) ^
hasLearningGoal (?lp , ?g )
^ hasCategory (?lp , ?s ) ^ ComposedBySubject (?g ,
?subj )
^ ComposedByConcept (?subj , ?concept )
^ ComposedByLearningObject (?concept , ?o )
^ recommendedForLearner (?o, ?s )
--> canUse (?p , ?o )
```

Listing 2 - An example SWRL rule that retrieves the most suitable teaching material for the specific student, based on his learning goal and learning style.

6. Conclusions

Technology is playing a key role in SC providing them with robust solutions that are of benefit to citizens. SC aim to incorporate smart solutions in their industrial, infrastructural, social and educational activities. Managing SC with intelligent technologies can allow to improve the quality of the services offered to citizens and make all processes more efficient. Linked data offers common representation based on ontologies and vocabularies to allow understanding and interoperable access of information resources in SC. One of the most important features of the linked data is their ability to enrich internal data archives with external data that could come from open data, statistics, DBpedia, Massive Open Online Courses and other LOD cloud sources. In this paper, we have presented the use of a LD framework using ontologies in the educational processes and learning activities in an Introduction to Algorithms and C Programming Language course. The approach performs a semantic annotation process assigning metadata to source code elements and key concepts to allow processing and understanding. The procedure of semantic annotation is applied on the basis of the developed ontologies; SPARQL queries and SWRL rules can be used to navigate the linked datasets and perform inference reasoning. The proposed framework makes use of open data, published ontologies and domain knowledge to construct a domain ontology consisting of common constructs, concepts, and instances. SWRL, commonly used for building inference mechanisms in ontology-based knowledge systems, allows to represent additional attributes that cannot naturally be inferred using traditional ontological models. Reasoning on enriched information can lead to interesting considerations and conclusions.

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JOURNAL OF e-LEARNING
AND KNOWLEDGE SOCIETY

www.je-lks.org

VOLUME 16 | ISSUE NO. 1 | APRIL 2020

**AN INTERNATIONAL AND OPEN ACCESS JOURNAL
BY THE ITALIAN E-LEARNING ASSOCIATION (SIE-L)**

www.sie-l.it

ISSN (online) 1971 - 8829 | ISSN (paper) 1826 - 6223