An Educational Game based on Images and Semantic Web Technologies

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***Abstract*—ISCOOL is an interactive educational game for text analysis and interpretation. It draws from several reference datasets, providing users with information about people, organisations and locations, as well as word definitions and historical facts that serve as the basis for reading comprehension and provide a wider context for information to be accessed, interpreted and understood. In game-play, users choose images to best illustrate a read text. The interactivity of the game encourages users to test their knowledge, and critically analyse what was read. ISCOOL was assessed by students with low literacy levels in English. The results show high levels of acceptance and applicability to genuine learning activities.**

***Keywords*-semantic web; text interpretation; serious games.**

I. Introduction

ISCOOL addresses an identified gap in educational resources. Rather than adding to existing tools that develop user skills in the "Three R's" (reading, writing and arithmetic), it focuses on developing analytical skills for critical thinking and information processing as part of opinion formation and informed decision-making.

The simple user-interface and in-built features help minimise barriers to engagement. Content can be changed to any subject matter, level of expertise, and granularity of data, eliminating the need for new materials, and bringing down costs. New content is automatically generated, and results are assessed by peers, meaning no additional strains are posed on educators' limited time.

Whilst applicable to many different demographics, two key user-groups have been identified, both representing a disadvantaged niche in the wider community: Firstly, those of low income households with limited access to educational facilities, many of whom have limited levels of literacy, and may be unable to effectively assess the correctness and accuracy of long documents, or those written in specialist jargon. Secondly, those with hearing impairment, who are engaging with material that in many ways constitutes a second language (their native tongue being sign language).

II. Background and Context

Developing countries face challenges in solving diverse and complex socio-economic problems, which include educational issues. There, improvements in education, teaching methods and knowledge construction have often had to be performed at and funded by the same resources as school dinners, teacher training and the introduction of new technologies in classrooms. In these circumstances, the priority of the latter over the former is clear. To maintain awareness of this reality, local country indices have been created to measure the improvements made within educational settings on an annual basis, and Brazil has reported a significant growth of basic education using IDEB (Brazilian Index of Basic Education Development) in recent years.

The IDEB reports the success and pass rates of students in Mathematics and Portuguese language and the average performance of schools assessed by a Brazilian governmental institute. According to this index, almost 70% of Brazilian municipal schools exceeded their goals while approximately 76% schools regulated by the stated exceeded its goals.

Although improvements made by developing countries are clear from local indices, larger, international ones such as the PISA (Programme for International Student Assessment) show that developing countries are still lagging behind on the global scale of education assessment: returning to Brazil as an example, the PISA report[1] ranks Brazilian education as between 57-60th from a total of 65 participant countries. This report demonstrates the need for further improvement in education in Brazil when directly compared to developed countries. Faced with limited budgets, the ratification of basic needs must by necessity take priority.

A new way of thinking about the production of knowledge was presented by Gibbons et al. [1], [2] when discussing the dynamics of science and research in contemporary societies. This approach considers both knowledge organisation and production (rather than production alone) as significant

[1]http://www.oecd.org/education/PISA-2012-results-brazil.pdf

elements of the process. Two of the modes suggested by Gibbons et al. have been used in this work: Mode 1, which refers to the organisation of teaching in discipline structures, that is, *knowledge-based disciplines* [3], and Mode 2, which comprises of diverse and varied ranges of research with a trans-disciplinary focus. The constant interaction between the nodes of the education network show a more socially responsible approach to knowledge-production.

This research combines aspects of different learning styles to help develop students' reading comprehension and to assess their understanding by using representative imagery. Our work is based on the heuristic framework of Mode 2, and makes use of technology to show the benefits and the potential of additional playfulness, facilitated by the use of scalable Semantic Web technologies to support the processes of acquiring knowledge, comprehending written material, and critically assessing learnt information.

III. Related Work

A. Semantic Approaches in Education

Several online approaches have been developed to support distance education, many of which are possible due to the development of semantic technologies. To cite an example familiar to most, the traditional highlighter pen was reimagined as an online version to support students enrolled on online courses [4]. It has several advantages over the original one: it can be shared between students, used to improve courses' contents as well as serve as a seed to link to new resources on the Web and it can help students to better understand course contents. Other e-learning tools [5] semantically analyse the content of posts to help instructors assessing forums. Educational forums have hundreds of individual messages and instructors can gain an overview of these discussion by the use of semantic technologies by summarising content into topics extracted from DBpedia. Another approach [6], [7] uses extracted topics from forum posts to recommend other discussions that may enrich the current one. ISCOOL uses similar methods to retrieve images from search engines.

B. Serious games

Combining entertainment and education stimulates students and encourages them to achieve learning goals [8]. Serious games captivate and engage students for specific purposes, such as developing new knowledge or acquiring specific skill sets. Kurkovsky [9] shows that games can contribute to improve retentions rates: difficult subjects often experience high drop-out rates, but these have been observed to decrease when games are used to supplement the course material [10]. Several works discuss the optimum balance between learning and entertainment [11], [12], [13], while others discuss how games impact education [14].

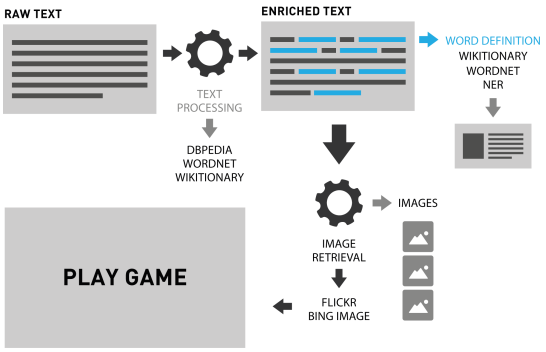

Figure 1. Game workflow.

C. Reading comprehension

The written world is a symbolic domain, and we must examine a range of individual representations to contextualise and recognise the intended word as something to be grasped in a new context. Only then can the semantics, or contained meaning, be understood. Zucoloto, *et al*. [15] show reading comprehension is directly related to the ability to make inferences from the text and our spheres of prior knowledge and experience. Individuals with low literacy who have difficulty with reading comprehension are at risk of failing to recognise words and misunderstand the intended meaning behind long and verbose pieces of writing: Salgado, *et al*. state that "consciousness of the word becomes concrete when there is the...understanding that a word is a distinguished linguistic unit from other units (such as phonemes and phrases), and that is an arbitrary symbol, which has no direct relationship with the object representing" [16], [17].

IV. ISCOOL

ISCOOL is an educational game platform that supports the learning of new languages, text analysis, and text interpretation. New and unique game instances are generated based on user input, allowing users to fulfill specific needs.

We describe the architecture of the ISCOOL platform focusing on the automated generation of image-based games. There are two key components: (i) text processing; and (ii) game creation (Figure 1). Both take advantage of semantic technologies, reference datasets, and online thesauri.

A. Text Processing

A player begins by uploading an excerpt of text. ISCOOL locates and classifies relevant elements: processing begins with named-entity recognition (NER), and specific identifiable entities (e.g. people, organisations, location) are linked to to relevant DBpedia pages using DBpedia Spotlight[2].

Any remaining words which are not recognised as entities are processed and linked to external data sources. ISCOOL

[2]http://dbpedia-spotlight.github.io/demo/

uses thesauri and dictionaries such as Wordnet[3] and Wiktionary[4] to extract, identify and provide correct definitions.

Once a text is processed, a link is drawn between the word and its definition, providing information about the lexical item in question. This is displayed in an optional dialogue box (accessed by clicking on the entity). This is a fundamental step, since queries used to retrieve the images that compose the game are based on these entity labels.

ISCOOL is centred around eading comprehension, text interpretation and analysis, and language learning. Traditional modes and methods for acquiring learning exclusively through audio-visual learning may not suit all students, and in the case of those withhearing impediments, traditional modes can be insufficient. The addition of visual material as a supporting element to language interpretation in a relaxed, multi-player environment allows students to learn by providing additional support more in line with visual and interpersonal learning styles. Assigning relevant images to uploaded texts requires the learners to engage with the text on several levels. The first and most straightforward step is to assign images to clearly defined and identified tangible entities in the text: nouns (places, people, things) and simple adjectives (colours). Intangible concepts (emotions, abstract notions) constitute the second stage of cognitive analysis, and require the student to furher engage with the content of the uploaded text.

B. Game Creation

ISCOOL generates an image-based game that takes advantage of the entities recognised in the previous step. The images used to create the game are retrieved using the Bing search engine and external sources (such as Bing Image API and Flickr): labels found in the first step are used as query terms. In order to achieve a broader representation, and to diversity the images, the categories of the entities (up to four levels up in the category tree) are also used as query terms.

The process to retrieve categorical terms is important as ISCOOL players can identify general and specific topics described in the text. For instance, when presented with a text regarding "Michael Jordan" (a famous former basketball player), the player can select a picture of the person in question, or a picture of one of its categories, i.e., a generic image of a basketball court or even a basketball. Depending on the proposed learning task by the teacher, (s)he may expect the player to select more general topics or more specific ones and thus be able to evaluate whether the player was able to identify relevant images amongst irrelevant ones. The categories associated with each entity in the text serves as a seed for the retrieval of further images to create the game. A relevance score is assigned (and used to score the game as it is played) for each image retrieved from Bing.

[3]http://wordnet.princeton.edu

[4]http://www.wiktionary.org

C. The game

One of the underlying assumptions on which ISCOOL is based is that if the player is able to identify entities represented as images in the game, they must have some degree of comprehension as to the content. Diversity in the choice of marked entity is awarded in the game: if a player chooses a number of representations for the same entity, other equally important aspects might be overlooked.

A level-specific timer limits the scope of each individual game. The more complicated the level, the shorter the time available - for beginners, there are five minutes, for intermediate and advanced, three and one minute respectively. The greater the level of difficulty, and the diversity of both the selected entities and images, the higher the pointsadded to the number of correct answers for the overall score.

The game has a simple 8-bit interface with a retro aspect. Instructions for the player (explaining how to engage with the game) are also provided (Figure 2).

V. Possible target audience

ISCOOL can be utilised in many educational contexts, but two are identified as being particularly likely to benefit:

- People with Low Literacy – a common problem in third world countries , often overlooked by governments. People with low levels of literacy may struggle to read and understand long and complex pieces of text, as well as those written in demanding registers or utilising specialist jargon. ISCOOL enables vocabulary enrichment and text interpretation through an interactive game in a friendly but competitive environment, which motivates students to learn and interact with others.
- People with hearing impairments, who can feel isolated due to language barriers and communication difficulties - communication through written medium is essentially via a second language (the first one being sign language). ISCOOL uses images to help with the learning process: images are more accessible and more familiar in the context of their daily lives, engaging with the game is comfortable, and motivates users to learn.

ISCOOL can be used in various different educational settings in primary and secondary education, as well as adult learners of various abilities and linguistic backgrounds. It can be used to support those with limited literacy or disabilities, but also for learning a secondary or other language.

VI. Evaluation and Results

A. Setup

ISCOOL was evaluated through a text interpretation activity by 25 Brazilian students in secondary education. They completed three steps: (i) reading the text; (i) using ISCOOL's enrichment functionalities to help them understand the text; and (iii) selecting the most representative figures according to their understanding of the text.

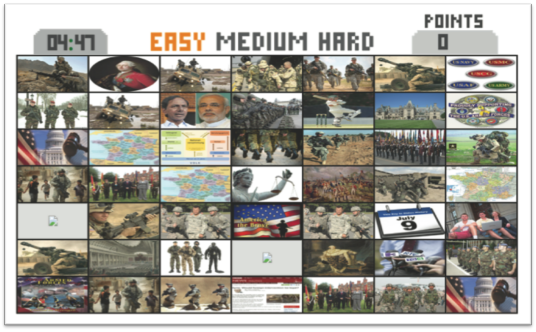

Figure 2. The Game.

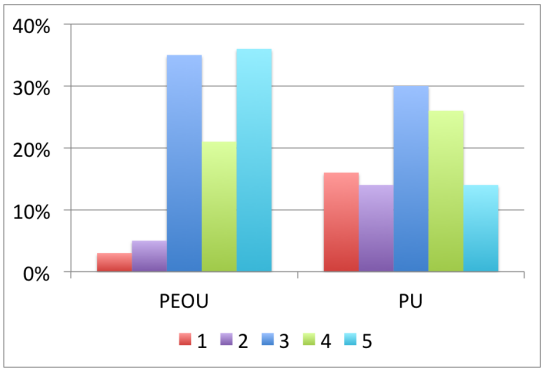

Figure 3. Percentual of each 5-point of Likert scale for survey questions regarding TAM model.

The students completed an optional questionnaire of 18 questions divided into four categories: six on User Characterization (UC), and four on each of Perceived Usefulness (PU), Perceived Ease-Of-Use (PEOU), and Open Questions (OQ). UC was used to characterized the participating students. The second and third categories reflect the Technology Acceptance Model (TAM) as proposed by Davis' influential Technology Acceptance Theory (which states there are two key aspects to user intention to adopt a new technology: PU and PEOU). PU measures a person's belief in a particular system to enhance his or her job performance, while PEOU refers to the degree to which a person believes a particular system will be free of effort [18]. OQ elicit opinions and impressions. The answers for PU and PEOU were collected on a five-point Likert scale.

B. Results

Following the evaluation strategy presented in the previous section, and Using the UC questions, we found that many students had a low level of proficiency in English (36% declared their proficiency as poor and very poor; 56% as fair; 8% as good and none as very good). This scenario illustrates that students with "low literacy" in English language (especially those learning other languages) are a possible target audience for ISCOOL. All students were familiar with computers between fair and very good (>2 in Likert scale); and 92% had used an educational game previously.

The results obtained by the TAM model are summarised in Figure 3. The average results of PEOU and PU were 3.82 and 3.08 respectively, indicating a positive perception for the applicability of the results (both were above average). The coefficient of internal consistency Cronbach's α of 0.83 for PEOU indicated a good reliability of the results. Unlike PEOU, PU obtained α=-0.40. This lead us to analyse the Cronbach's α values excluding each of the PU questions and found a considerable increase (to 0.52) when one particular question was excluded. Asking whether students were feeling under assessment while playing (a higher Likert scale value was taken to indicate not feeling assessed while playing) was a controversial question, the results possibly reflecting the location where the experiment was conducted, i.e. school environment, during a regular class.

For the OQ questions, 73% of the students would recommend ISCOOL to a friend; 76% were interested in sharing the game's results, and 80% would like other disciplines to incorporate educational games such as ISCOOL to teaching.

Some students reported difficulties reading the English text but that ISCOOL was able to assist them during the task. Other students expressed a desire to play in their native tongue (i.e. Portuguese) to solve interpretative activities. Regarding to the game interface, some students suggested that the figures presented could be of a larger size.

VII. Discussion and Outlook

Images play an important role in the processes of teaching, learning and text interpretation at all levels of education. Visual aids are irreplaceable as a tool for helping members of the two target demographics to derive meaning from writing, and their use in ISCOOL enables these groups to engage with an educational tool and acquire new skills and levels of competence. As Truax et al. [19] said about semantic conventions, "The semantic rules a language user utilises reflect a child's understanding of how his or her community organises content meaning linguistically for representation in the sentences, phrases, and words of a discourse". Content meaning is organized and coded linguistically by repeated experiences and "a language user becomes more adept at understanding not only the literal meanings of words, but also their nuances and how narrative stories are organized".

ISCOOL was evaluated in a real application scenario by students with low literacy levels in English. Positive results were obtained relating to the students opinions about PU and PEOU: they were also obtained in relation to the receptivity of the students to ISCOOL reinforced by their interest in: (i) sharing experiences while playing with other users; (ii) recommending the game to their friends; and (iii) applying games to their learning process.

The game uses images extracted automatically from external sources, based on decisions made by players, and may

contain instances that do not fully or adequately represent the text. To circumvent this problem, a number of images are retrieved for each entity, and those least clicked may not be shown in the future. We are currently evaluating the use of ISCOOL using natural language processing tools, and intend to identify images that represent not only entities in terms of knowledge references, but also incorporate more complex concepts and abstract notions to better capture the players' comprehension of the text. ISCOOL can be accessed at: http://research.ccead.puc-rio.br/iscool/.

Acknowledgment

Partly funded by CNPq and FAPERJ under grant 444976/2014-0 and E-26-102.256/2013, respectively.

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