EJPCE
Eurasian Journal of Physics and Chemistry Education

Eurasian J. Phys. & Chem. Educ. 4(1): 65-77, 2012

journal homepage: http://www.eurasianjournals.com/index.php/ejpce

Using Text-to-Speech Generated Audio Files for Learning Chemistry in Higher Education

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Received: 25 July 2011 – Revised: 21 December 2011 – Accepted: 27 December 2011

Abstract

In this paper, we describe a case study of using text-to-speech software to record audio files as complementary materials available to students of the first year chemistry course in the human nutrition and dietetics degree program at the University of Granada (Spain). We have carried out a survey about the interests of the students, assessed the usefulness of the materials for students with learning disabilities and partial visual impairment, and tested the potential to establish these materials as part of an effective mobile-learning platform. This type of survey of the final user of new learning materials is a crucial step for effective development of universally accessible contents and mobile-learning platforms. The majority of the students showed a great interest on the use of the audio files as complementary materials, as well as expressed their positive opinion on the audio files as supporting materials for studentship with learning disabilities and partial visual impairment. On the other hand, the usefulness of our audio files as components of a mobile-learning platform remains to be established since the students were not remarkably prone to use them in such situations.

Keywords: Chemistry learning, Dyslexia, Mobile-learning, Multi-sensory learning, Text-to-speech software

Introduction

The use of technology as a fundamental support in teaching and learning continues to play a crucial role in dealing with learning disabilities. Assistive technology is a valuable tool to enhance the possibilities of reaching appropriate concepts and skills by students with learning disabilities or physical impairments, such as blindness or low vision (Supalo, et al., 2009). These technologies include the use of specific tools, technical improvements in software and hardware, alternative access systems, and accessible educational websites. The aim of assistive technology in teaching is to provide access to information to those students with difficulties, thus improving the equality of opportunity and following the principles of universal access. When students exhibit signs of learning difficulty in the early stages of learning and in elementary school, it is common for teachers to implement unique, personalized strategies. These strategies are not so commonly implemented in secondary education. In higher education, established methodologies to provide universal access are rarely found. The convergence policy in Europe to create a European Higher Education Area (EHEA) puts efforts in ensuring more comparable, compatible and coherent systems of higher education among the member countries. The implementation of the EHEA is based on the principles of universal access and the pursuit of higher education excellence. This increase in

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ISSN: 1306-3049,

excellence and information accessibility is becoming a major driving force for higher education teachers and researchers, who are adapting their teaching methodologies accordingly.

A well-demonstrated strategy to enhance the learning process of students with learning difficulties or attention disorders is the use of a multisensory teaching approach. In multisensory teaching, the information flows through as many senses as possible, conveying feedback and synergy to aid the comprehension of the information. The enhancement is rooted in the fact that a flow of information through multiple channels facilitates the overcoming of limited local capabilities by strengthening parallel pathways (Clark & Paivio, 1991) and more easily forming long-lasting mental representations (Bagui, 1998). In addition, multisensory learning is probably a more natural way of learning because the human brain is evolved to learn through experience in a multisensorial environment (Shams & Seitz, 2008), as Montessori mastered in her acclaimed methodology (Montessori, 1912). Multisensorial learning also boosts memory (Lehmann & Murray, 2005) and generally increases the learning rate when compared to visual-only based learning (Seitz, Kim, & Shams, 2006). Multisensory teaching and specifically speaking-computer based methodologies have not only proven efficient in treating difficulties such as dyslexia but also proven beneficial for other disorders such as dyseidetic syndrome (visual stress caused by printed words) and phonological problems (Scrase, 1998). Notably, the complementary multimedia materials must be comprehensible to accurately affect the correct mental processes; otherwise, if the amount of information is excessive and incomprehensible, the learning process may be disrupted (Mayer, Heiser, & Lonn, 2001).

In recent years, research has pointed out the increasing use of technology in assisting students with learning and reading difficulties, attention disorders, speech improvements, and so forth. It has been demonstrated that the use of text-to-speech (TTS) software, especially with the improvements in natural voice simulators, enhances reading fluency, understanding, and concentration in students with attention disorders (Elkind, 1998; Hecker, et al., 2002; Wise, Ring & Olson, 2000). TTS software generates spoken sounds and words from computer text. Recently, this type of software has been majorly improved in terms of natural voice simulators, contextualized vocalization, feedback pronunciation, and punctuation recognition. TTS software facilitates the interpretation of text by students with reading difficulties, boosting the comprehension process (Hecker & Engstrom, 2005). Moreover, strengthening the association between phonemes and graphemes by means of computer-based multisensory learning has improved reading and writing skills of children with developmental dyslexia (Kast et al., 2007).

Additionally, it has been pointed out that the benefits of listening while reading may not be exclusive to students with learning disabilities and that they also apply to the general student. Specifically, when focusing on e-learning, the digitization of study content is the first step toward providing contextualized materials that may be accessible through computers, electronic media, or web-based learning platforms. The growth of the World Wide Web and the accessibility of portable computers and mobile phones connected to the Internet provide an excellent basis for the development of e-learning methodologies, and more specifically, of online education and mobile-learning (m-learning) techniques (Olsevicova, 2006; Rajasingham, 2011). Although the main tools and players are in place, the current efforts to provide a useful platform for m-learning are still in a nascent stage. Some initiatives for developing m-learning and e-learning platforms in higher education have not completely fulfilled the created expectations (Carvalho, et al., 2008; Hoppe, 2006; Keegan, et al., 2007), resulting in some continued controversy about the viability of long-lasting learning via discontinued, perhaps short, learning periods (Rajasingham, 2011). Therefore, it seems

evident that a thorough planning and design of materials available via an m-learning platform, the conceptual loading, and the methodology, must be considered prior to setting the platform running.

Based on this background, we describe in this paper a study of using TTS generated audio files as complementary materials available to students of the first year chemistry course within the human nutrition and dietetics degree at the University of Granada (UGR) in Spain. Herein, we have performed a preliminary study of the viability of the project, surveyed the interest of the students, and assessed the usefulness of the materials for students with learning disabilities and partial visual impairment. Likewise, after the students had access to the TTS audio files for some time; we carried out a comparative study of the students' opinions on the TTS-audio materials and their potential to establish an m-learning platform.

Methodology

1. Text-to-speech software and preparation of the audio files.

In this work, we have digitized the handouts for the first course of chemistry within the human nutrition and dietetics degree at the UGR (Spain), and compiled TTS software-generated audio files as complementary materials available to the students. Following use of the materials, we interrogated the involved students about their experiences using the audio files and their opinions on the usefulness of these materials for people with learning disabilities and partial visual impairment.

Table 1. The TTS software must be trained to correctly read the main text, mathematical equations, symbolic representations, and chemical formulae in the students' handouts. This table illustrates the preparation of what we have called *"TTS-ready text"*.

Extract of the *Student handout's text*	Preparation of the *TTS-ready text*
Given the system is open to the atmosphere, the external and internal pressure are always the same ($\boldsymbol{P_{ext}} = \boldsymbol{P}$), and ΔH is given by: $\Delta H = q - P_{ext}\,\Delta V + P\,\Delta V = q$ $\Delta H = q_P$	- Given the system is open to the atmosphere, the external and internal pressure are always the same, and the enthalpy change is given by: - the heat, q, minus the external pressure times the volume change, plus the internal pressure times the volume change - reaching that the enthalpy change equals the heat at constant pressure.

As discussed in the introduction, the benefits of TTS software have been demonstrated to improve reading and comprehension skills in students with learning difficulties (Elkind, 1998; Hecker, et al., 2002; Hecker & Engstrom, 2005; Kast, et al., 2007; Wise, et al., 2000). However, in the study of chemistry at the higher education level, there are additional comprehension factors that must be taken into account, such as the understanding of chemical formulae and reactions and the comprehension of equations, numerical and abstract values, dimensional units, and so forth. The TTS software must be programmed to interpret the chemical formulae and word sounds associated with certain variables so the equations can be properly read. Given this additional difficulty, the direct use of TTS software in scientific/chemistry texts is not as straightforward as it would be when applied to conventional or nontechnical text. In order to overcome this translation obstacle, our approach was to create TTS generated audio files that should accompany the text of each unit of the subject. The first step was, hence, to appropriately train the TTS software in order to correctly

reading the chemical reactions, mathematical expressions, dimension units, and so forth. This involves modifying the *"student handout's text"* into the *"TTS-ready text"*. Table 1 illustrates these modifications in an extract of one of the units taught.

The TTS software that we employed was TextaVoz (software from the company Rehasoft, Spain), which features natural-sounding speech and vocalization and offers the possibility of exporting the reading sounds into audio files. Once the text was revised, the MP3 audio files were generated by the TTS software. The audio files were uploaded the web-based educational platform of the UGR (http://swad.ugr.es), and made available to the students registered in the corresponding course. Within the web-based teaching platform the enrolled students had at their disposal the text handouts for each unit and the complementary TTS-audio file. The students participating in the project were encouraged to use the TTS-audio files at their own discretion in different moments of study. However, it was out of the scope of this study to measure the actual usage of the TTS-audio files and correlate it with the learning performance. The detailed following of the TTS-audio files usage could be an interesting improvement for continuing the research on this matter (Copley, 2007).

2. Opinion surveys.

We designed the following survey to probe the inclination and opinion of the students toward the TTS-audio files as complementary study materials. The questions were stacked in two different aspects: questions on the general application of the TTS-audio files, and questions on specific usefulness on the audio files. The response items were rated: "not at all/nothing", "scarcely", "rather/fairly", and "very much/a lot". A translated representation of the survey is shown in the following Table 2:

Table 2. Translated representation of the employed survey.

1. Questions on general application	not at all / nothing	scarcely	rather / fairly	very much / a lot
1.1. Are the TTS-audio files useful for students with reading/writing difficulties, such as dyslexia?				
1.2. Are the TTS-audio files useful for students with partial visual impairment?				
1.3. Are the TTS-audio files useful for all the studentship in general?				
2. **Questions on specific usefulness**				
2.1. Would you use the audio files while studying/reading the handouts at home, in a library, or in any other place of study?				
2.2. Are the audio files useful to learn how some mathematical expressions and chemical representations are read?				
2.3. Are the audio files useful when you have missed one of the class lectures?				
2.4. Would you play the files while doing other activities (e.g., sports, waiting for the bus)?				

In a first step, a prescreening survey was proposed to the students who agreed to be a part of the project. Prior to receiving the audio materials and just after reading the main goals of the project, the students answered the survey on Table 2. This prescreening evaluates the

expectations of the students over the project and their will to use the TTS-audio files in their daily study.

After the audio files were available on the course's web platform, along with the students' handouts for the course, the students were surveyed again using the same questions in Table 2. They were also asked to give their impressions of the project. If their opinion on certain issues notably improved or worsened, they were asked to validate the reasons for the change.

3. Sample description.

The percentage of enrolled students among the total registered students in the course was 23 % (N = 15 out of the total population of 65). The gender heterogeneity in the total population was 72% women. The surveyed subpopulation assumes that the sample error was about 17% with a confidence level of 90% (Alòs, 1995). Gender and age effects were also analyzed. Regarding gender effects, the surveyed subpopulation presented heterogeneity of 60 % women (N_{women} = 9), approximately representing the heterogeneity of the global population. The age effects were an interesting issue to focus. The chemistry course is a subject found in the first year of the human nutrition and dietetics degree syllabus at the UGR, so the conventional age of starting these studies is about 18–20 years old. However, this degree is a very common choice for postgraduates who want to achieve a second degree, so the average age of the students increases. We set a threshold for the analysis of the data of 21 years old. The surveyed subpopulation presented 40% of under-21 individuals ($N_{under\text{-}21}$ = 6, $N_{over\text{-}21}$ = 9).

Results

1. Prescreening survey

Prior to making the audio materials available to the students enrolled in the project, the prescreening survey was performed by giving them a text explaining the general aims and possible benefits and deliverables of the project.

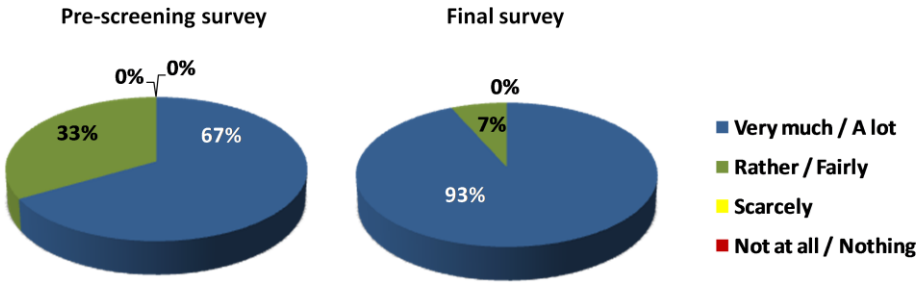

Figure 1. Comparative results of the pre-screening and final surveys to question 1.1.: whether the audio files could be useful for students with reading / writing difficulties, such as dyslexia.

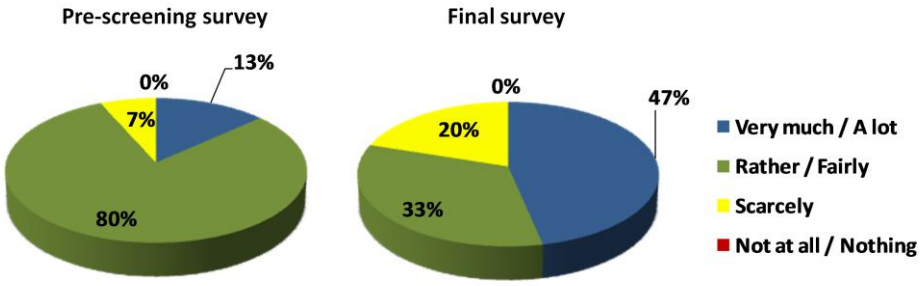

Figure 2. Comparative results of the pre-screening and final surveys to question 1.3.: whether the audio files could be useful for all students in general.

The analysis of the prescreening surveys showed that 67% of the students thought that the audio files could be very useful for students with learning or reading disabilities such as dyslexia. The other 33% believed that the material could be rather useful for people with those problems (question 1.1., Figure 1). Similarly, 87% of those polled believed that the audio files might be especially interesting for people with partial sight disabilities, while the remaining 13% stated that the audio files could be fairly useful (question 1.2). Notably, none of the polled students declared that the audio material would be useless or just scarcely useful for people with learning or reading disabilities or partial sight impairment. Concerning the utility of the audio files for all students (question 1.3.), the preliminary survey showed that only 13% considered that the materials would be very useful, and 80% thought that the TTS files could be rather useful (Figure 2).

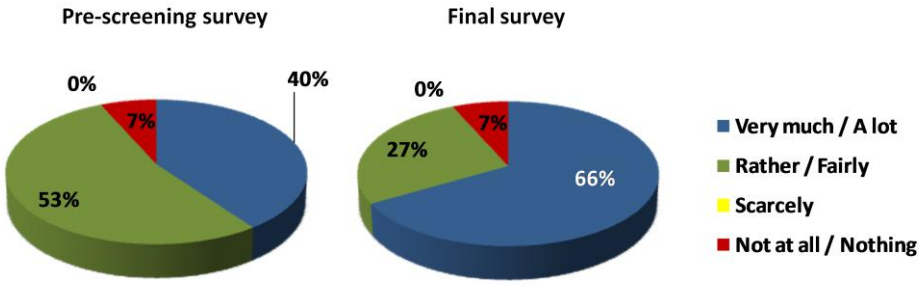

Figure 3. Comparative results of the pre-screening and final surveys to question 2.1.: whether the students would use the audio files while studying/reading the handouts at home, in a library, or in any other place of study.

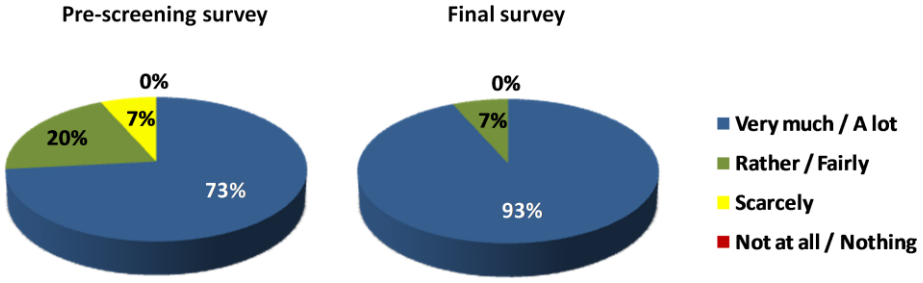

Figure 4. Comparative results of the pre-screening and final surveys to question 2.2.: whether the audio files could be useful to learn how some mathematical expressions and chemical formulae are read.

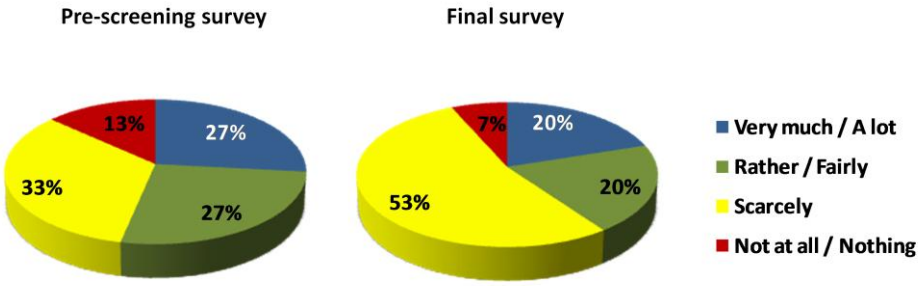

Figure 5. Comparative results of the pre-screening and final surveys to question 2.4.: whether the students would play the files while doing other activities (sports, waiting for the bus).

When they were asked about their interest in using this multisensory tool in different situations, 93% of the surveyed students stated that they would play the audio files (40% very much; 53% fairly) simultaneously while reading and studying the contents of the course at home or at the library (question 2.1., Figure 3). Moreover, 93% thought that the files might be very or fairly useful, especially for learning how to correctly read chemical formulae or mathematical expressions because sometimes they do not know the meaning of some symbols or variables (question 2.2.). Only 7% of those surveyed believed that this methodology would be just of little usefulness for this aim (Figure 4). Another question was related to the help that the material could provide when the student does not attend a particular lecture (question 2.3.) In this case, again, 93% of the polled thought that the files could be very or rather (53% and 40%, respectively) useful. Regarding the question about the application of the files in a mobile-learning platform (question 2.4.), such as podcasting (this is listening to the materials on personal portable media players while carrying out another activity such as sports; Copley, 2007; Evans, 2008; Holbrook & Dupont, 2011; O'Bannon, et al., 2011), 54% of students surveyed declared that they would do so very much or fairly, whereas 33% stated they would do so scarcely, and 13% would not play them at all (Figure 5).

2. Post-usage survey

After this first assessment, the audio files were made available to the students enrolled in the project, along with the course handouts, on the UGR web platform. The students had the chance to download the audio files, play them, and use them in their daily study tasks and in personal media players while doing other activities. Although the students were encouraged to used the TTS-audio files in different moments and situations of study, there was little control over the actual usage of the files. After using the TTS-audio materials, the enrolled students retook the initial survey; this gave them the opportunity to make their final assessments on the audio materials and to discuss whether their opinions had changed about the suitability and utility of the multisensory material.

This final assessment survey showed that the percentage of students who declared that the audio files could be very useful for people with learning or reading disabilities increased to 93%, and the remaining 7% stated that the files would be rather useful (question 1.1., Figure 1). These results indicate that after listening to the files, the students realized the suitability of the proposed methodology and how it can help people with the stated disabilities. Regarding the suitability of the files for people with partial sight impairment (question 1.2.), the results were similar to those obtained in the preliminary survey. All of the students polled thought that this learning tool could be very or rather useful (87% and 13%, respectively) for students with these problems. The opinion of the surveyed students about the utility of the audio material for general students of the course (question 1.3.) underwent a

considerable change once the audio files were actually employed. The percentage of students who thought that the audio material could be very useful to the totality of the students increased from 13% to 47%. However, the percentage of students who expressed that the files might be rather useful decreased to 33%, and the remaining 20% declared that the utility was poor for the general student (Figure 2).

In the second series of questions, again, 93% of the students stated that they would play the audio files simultaneously while reading and studying the printed handouts at home or at the library (question 2.1.). However, the percentage of those who declared that they would use the audio files a lot while studying increased from 40% to 66% (Figure 3). For this question, 40% of the students marked a higher ranking in the answer item than they had in the prescreening survey, showing an increase in the willingness to actually use the audio files while studying. However, 13% marked a lower ranking in the final survey compared to the initial screening. When questioned about the usefulness of the TTS files for proper reading of the chemical formulae and mathematical equations (question 2.2.), the results improved drastically. In contrast to the preliminary survey, now all of the polled students believed the audio files could be very or fairly useful for these purposes, with 93% choosing the maximum rank in the response item (Figure 4). In the final survey, 27% of the students showed an improved opinion in response to this question. On the following question, the percentage of students who believed that this audio methodology could be very or rather useful when they do not attend to a lecture (question 2.3.) decreased to 87% (40% and 47%, respectively), and now the remaining 13% believed that it would be of scarce help or no help at all in those situations. The responses to the question related to the possibility of playing the audio files while doing other activities (question 2.4.) showed a decrease. Only 40% of the polled students asserted that they would play the files (very much or fairly) while doing other activities, and 60% stated that they would barely use them or not use them at all while doing other activities (Figure 5).

3. Gender and age effects.

Arranging the results in terms of gender, very few differences were found in most of the questions.

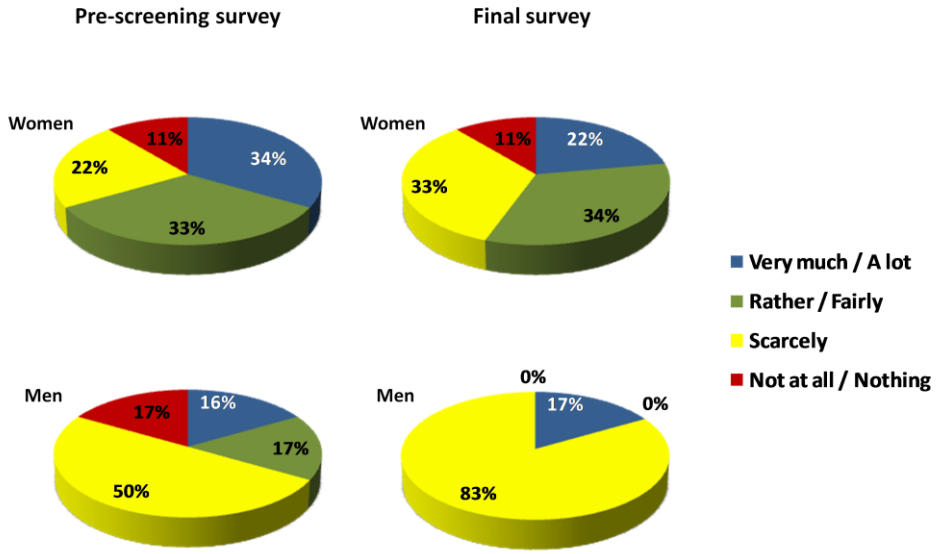

Figure 6. Comparative results of the pre-screening and final surveys, arranged by gender, to question 2.4.: whether the students would play the files while doing other activities (sports, waiting for the bus).

The most interesting result was found in question 2.4., about the use of the audio files in personal portable media players while conducting a different activity. In the prescreening survey, only 33% of the men indicated that they would use the files fairly or a lot while performing other activities. In contrast, the percentage of women answering fairly or a lot to this question was 67% (Figure 6). In the final survey, after having used the audio files, the percentage of women and men stating that they would use the audio files fairly/a lot during other activities decreased in both cases, although it was still much higher for women (56%) than for men (17%; Figure 6). These results clearly indicate a wider motivation of enrolled women for the m-learning methodologies and the inclination of women to deal with simultaneous tasks.

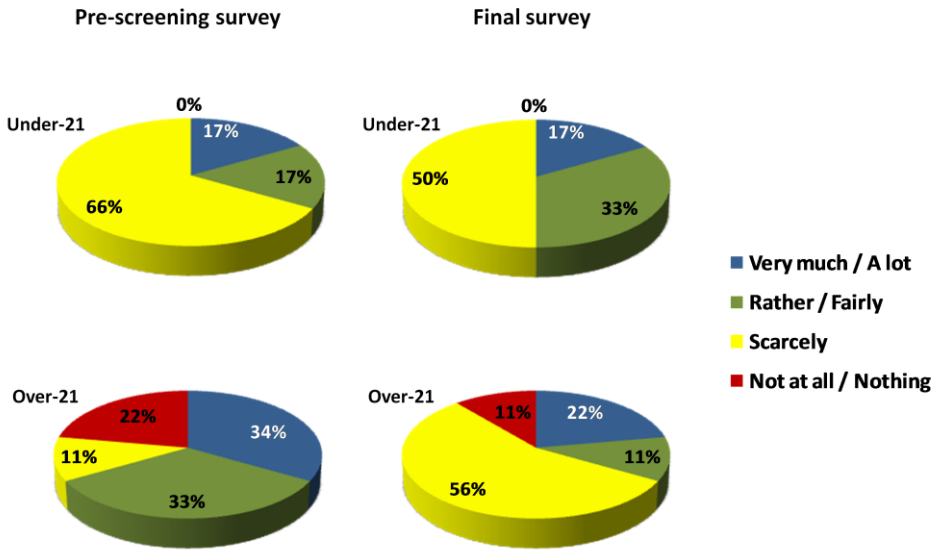

Figure 7. Comparative results of the pre-screening and final surveys, arranged by age, to question 2.4.: whether the students would play the files while doing other activity (sports, waiting for the bus,…).

Focusing on differences in age also leads to interesting results. The chemistry course is a subject found in the first year of the human nutrition and dietetics degree syllabus at the UGR, so the conventional age of starting these studies is about 18–20 years old. However, this degree is a very common choice for postgraduates who want to achieve a second degree, so the average age of the students increases. Differences in age may lead to a different approach of the students towards multimedia learning methodologies (Van Gerven, et al., 2003), so we set a threshold for the analysis of the data of 21 years old. Again, the most striking differences were found in the question 2.4., regarding the use of the audio materials in portable players while doing other activities. In the prescreening survey, only 34% of the surveyed students under 21 were willing to use the files while carrying out other activities fairly or very much, while the percentage was 67% for students older than 21 (Figure 7). This is a surprising result, because one would expect younger students to be more prone to using novel learning methodologies. However, once the files were used by the students, the percentage of students under 21 that would use the files fairly or a lot while doing other activities increased to 50%, whereas the percentage for students older than 21 drastically decreased to 33% (Figure 7). This result signifies that the expectations of the students above 21 were higher at the beginning, and that these students changed their minds after having tried the audio materials. The opposite effect was found in the students under 21, who were less

prone to using the audio files while performing other activities at the beginning; for these students, the attraction of using the files during other activities slightly increased.

Discussion

In this paper we have surveyed the inclination of the undergraduate students of the chemistry course in the human nutrition and dietetics degree at the University of Granada (Spain) towards the usage of TTS-generated audio files as study materials, complementary to their printed handouts. The students were polled through a prescreening survey, evaluating their expectations and preliminary opinions. Then, the TTS-audio files were made available to the students at the web-based teaching platform of the UGR. Subsequently, the students were surveyed again, probing whether the TTS-audio files had complied with the initial expectations, and evaluating the student's final opinion. Herein, we have not assessed whether the use of the audio files improved the academic performances of the students enrolled in the project because we did not control the amount of time that the students actually used the audio files in their daily tasks. We were more interested in their opinions on the generated materials as a useful, additional learning tool. One of the possible improvements of this study is to follow the actual usage of the audio files by counting file downloads, on-line file reproductions, surveying hours and methods of usage of the files by the studentship (Copley, 2007).

The results of this study indicate that after usage of the TTS-audio complementary materials, the students realized the suitability of the proposed methodology and how it can help people with specific learning needs, such as partial sight impairment (Supalo, 2005), learning difficulties or attention disorders. Many different strategies are being developed to ensure the accessibility of the information to blind or low vision chemistry students, such as adaptive tools and tactile technology (Jones, et al., 2006; C. Supalo, 2005) or web portal applications (Pereira, et al., 2010). The TTS-audio materials that we have produced lay within this category. Furthermore, multimodal and multisensorial teaching has been demonstrated to enhance the learning process (Shams & Seitz, 2008), boost memory (Lehmann & Murray, 2005), and increase the learning rate (Seitz, Kim & Shams, 2006). Multimedia technologies provide an excellent basis for the development of multimodal learning. Nevertheless, there exist multiple reports questioning that the benefits of multimedia learning are solely caused by the nature of the multimedia instruction, and suggesting that such benefits can be achieved by other combination of factors, not necessarily related to the multimedia nature of the materials (Clark, 2001; Clark & Feldon, 2005; Kozma & Russell, 2005). On the one hand, overloaded multimedia study materials can be very exciting and visually attractive, but on the other hand, they may decrease the learning rate by presenting seductive but irrelevant distractions (Clark & Feldon, 2005; Mayer, 2001). The TTS-audio materials that we have prepared do not show such drawbacks, since they are mainly intended to be used simultaneously to the printed handouts, which represent the written contents of each unit of the course. The opinion of the polled students demonstrates their favorable inclination to use the TTS-audio files in such a way. For instance, one of the questions in which the students showed a great interest in using the audio file was to improve the learning of how to read the mathematical expressions and chemical formulations (question 2.2). The student's opinion is in agreement with experimental studies that showed that multimodal learning enhances the link between representations and the concepts studied (Jewitt, 2009; Tytler & Prain, 2009). In our work, the majority of the students also found the TTS-audio files to be very or rather useful in case they miss a lecture (question 2.3.). This result is in good agreement with the recent report by Holbrook and Dupont (2011), which showed that many undergraduate science students considered very important to have access to lecture podcasts in their decision to miss class. In contrast, Copley (2007), by analyzing the usage of lecture podcasts that

comprise lecture slides and complementary audio, did find little impact on lecture attendance. However, Holbrook and Dupont (2011) conclude that the learning benefits of lecture podcasts overcome the higher inclination to miss lectures that some students may have.

The availability of multimedia materials, such as lecture podcasting or our TTS-audio files, may represent the basis of an m-learning platform, in which contextualized materials can be accessed from portable units facilitating learning in different situations (Olsevicova, 2006). Nowadays, there still exists controversy on the fact that discontinued learning, implied by an m-learning platform, may not provide a viable approach to reach long-lasting mental representations (Rajasingham, 2011), and many recent reports have provided inconclusive results (Carvalho, et al., 2008; Hoppe, 2006; Keegan, et al., 2007). Our results clearly show the controversy and difficulty of designing a proper, effective m-learning methodology. Evans (2008) reported a survey research work in which the students perceived that audio podcasts were a more effective learning tools than textbooks or their class notes. The flexibility of usage of audio files and podcasts may present a great potential as an innovative learning tool (Evans, 2008; Hew, 2009; Vogt, et al., 2010), leading towards the substitution of the traditional lecture into in-class demonstration and guided practice while the lectures would be provided via podcasts (O'Bannon, et al., 2011). However, our results did not show such an optimistic situation, in line with other researchers (Copley, 2007; Rajasingham, 2011).

Conclusions

The results shown here are in agreement with recent similar research studies. It is well documented that the multisensory approach is helpful for students with learning or reading difficulties, and our results show that students believe our materials could be beneficial in such cases. Similarly, students found that our audio materials could also be helpful to students with partial sight impairment. Finally, most of the students found that the audio files were very helpful to learn how to read chemical expressions and mathematical equations, especially in cases in which they would miss a lecture. However, the utility of the audio files for students as m-learning materials is not yet clear; listening to audio files in personal portable media players while performing another activity is not yet an approach that our students feel comfortable with. This result is in concurrence with the current controversy on whether m-learning would yield long-lasting knowledge. A further study can be performed in the future, dealing with the actual usage of the TTS-audio files by the students, as well as following academic achievements by students using the audio materials. We believe that undergoing a planning strategy for a better design of m-learning platforms is crucial. Likewise, the final users, the students, must play an active role in building effective m-learning platforms; their opinions on what might and might not work for them must be an important consideration in the design of m-learning initiatives.

Acknowledgements: This project has been funded by grant 10-31 from the Unidad de Innovacion Docente (Universidad de Granada).

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