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How to Improve Understanding Using 3D Objects in Ebooks and Augmented Reality

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Abstract: The development of educational materials for computer equipment and mobile devices, uses only a small fraction of the graphic possibilities that these devices allow today. Sometimes, they are digital or online versions of the same documents we used to teach with.

This paper describes work in progress about two educational materials for undergraduate students in which we use rotatable three-dimensional elements embedded in digital documents taking effectively advantage of the graphics capabilities of mobile devices. These elements are 3D models that have been incorporated into e-books to explain abstract concepts in subjects such as Physics and Descriptive Geometry. With them, we have verified that students understand almost instantly what the two-dimensional drawings stand for and what the projections represent in the planes corresponding to the view (top, front or lateral) of an object. The material described has also been highly appreciated by teachers of these two subjects.

The difficulty that students have to imagine the volume represented in the two-dimensional drawings is due to the fact that they have not yet fully acquired the cognitive structures of spatial thinking. In response to this circumstance, it was proposed the possibility of having three-dimensional objects that could be rotated within the didactic material.

The procedure developed for this project, allows the same 3D object file inserted into the eBook, to be uploaded to an augmented reality app to be displayed on a printed companion material. This advantage allowed us to develop two useful and attractive educational materials with the same work effort.

Key words: eBook, 3D, digital objects, augmented reality

1. Introduction

Physics and descriptive geometry are sciences based on real objects, so it is imperative to understand the object in space and what vectors and lines represent. In practice, Descriptive Geometry is taught by alluding to the student's intuition in order to solve a certain exercise, however if the student fails to put his intuition into practice because he has not yet developed spatial cognitive structures, comprehension is not performed. When this happens, the student only focuses on the sequential steps of a given drawing procedure, thus giving them an automatic solution.

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In Physics, a vector is a mathematical concept that has both magnitude and direction relate to a coordinate system. This is difficult to represent in a two-dimensional drawing, either in a flat projection or in a perspective view. The result is confusing to the student who might not understand the array of vectors and forces presented to him not by the arrangement itself but by not understanding the location and direction of such vectors.

For students of Statics as well as for those of Descriptive Geometry, the concepts taught in these subjects are the foundation to acquire more complex knowledge in their professional careers. Therefore, comprehension as well as acquiring the cognitive skills necessary for this understanding to occur, are two essential problems of education.

Aware of that problem, we set ourselves the task of digitally constructing all the exercises of these two subjects, Physics/Statics and Descriptive Geometry, knowing that the technology would allow us to combine explanatory texts and rotatable digital objects within the same educational product: an eBook. These 3D movable objects allowed us to develop a new and different educational material for the different way of learning of today's students.

2. Theoretical Framework

There are studies that explain the age when youngsters acquire three-dimensional cognitive abilities, however, the spatial reasoning skills including the ability to represent objects from multiple perspectives, still needs to be strengthened until it enables them to produce accurate representations of objects viewed on different projection planes.

It has been said that exposure to better computer graphics, virtual worlds and video games could have favored the spatial notion ability, but this is not necessarily reflected during courses. On the contrary, the familiarity that students have with these graphic elements, detached them, at least motivationally, from bi-dimensional educational methods.

As teacher of Industrial Design during thirteen years, it is clear to see that there is also a relationship between people's spatial thinking capacity and their ability to create. Students with greater cognitive capacity of three-dimensional thinking, make more complete and creative designs as they better conceptualize their ideas.

All educational materials that exercise and foster student’s three-dimensional reasoning skills will be reflected in an increase of their creativity, not only their understanding. The motivation as teachers should make us explore the best visualization resources that technology allows and incorporate them in educational materials.

3. Methodology.

For the development of the projects described in this paper, we began by choosing the optimal material to cover the syllabus of each of the subjects. Once refined the scope and approach for each topic, we chose those exercises that would be built in 3D. At the same time, explanatory texts were written, technical drawings were made and images for the graphic interface were elaborated.

From the experience of previous projects, we defined the use of iBooks Author for the development of eBooks for iPad and the use of the app Aurasma for the augmented reality version. In part, this decision was made because the university where this project was carried out has classrooms equipped with iPads for students to work with.

Several CAD softwares were tested for the construction of 3D objects. The best results were obtained from

3ds Max. Additionally tests were carried out with Maya, Rhinoceros, Solid Works and AutoCAD. Several constructive methods were also tested (extrusion, loft, shell, etc.).

This stage of tests was deadening since it was intended to reach an optimal method before starting the production of the rest of the 3D objects.

Each 3d object went through the process of scaling, orienting, mapping, texturizing, lighting and exporting it, to be incorporated into the iBooks Author and the Aurasma service. Both programs require the 3D file in a .dae format so our interest was that the construction method would be useful for both programs. In this way, testing process ended until the file was able to work correctly in both applications, spinning it in the iBooks app for iPad and deploying through mobile devices from the Aurasma application.

Although some programs export to .dae format, the only useful files were obtained with the Open COLLADA[1] exporter, installing previously the plugin for the CAD program used, in our case 3Ds Max.

Once the digital construction process was determined, we began to elaborate the images that would be used to accompany the 3D models as projection planes. For Descriptive Geometry, this is imperative because students are expected to see how the object coincides with the projection on the front, top or lateral views. For that purpose, we used images in .jpg format applied as Bitmap in Standard material. Opacity reduction was applied to avoid obstructing the view of the 3D object while rotating it. A planar UVW map was applied from the CAD modeler so that the object carried this information from its origin.

Both projects have dozens of 3D objects so it was very critical to decide from the beginning the nomenclature of the files, the associated images and the exercises to which they corresponded.

Creating an eBook with ibooks Author is a straightforward process. To facilitate its elaboration is advisable to have all the material previously in a Word document. It should be pointed out that the formulas required for the textual part of the Physics eBook were distorted many times. The files came from the software “Mathematica” and were exported from there as RTF to avoid any modification in the formulas. To avoid the mistakes that began to be detected and reduce the exhaustive revisions that could have ended in serious errors, many of the formulas were separated as images, capturing them from RTF document at the same time that the text was being copied to iBooks Author.

To embed 3d objects, iBooks Author has a function (3d widget) that incorporates them directly to the page where they need to be placed. They can lay next to the text to which they correspond and scale them as needed. The .dae file is dragged directly to the widget from its position on the hard disk where it must be stored next to the jpg images used to map it.

The use of the eBook during classes was done differently in Statics than in Descriptive Geometry according to the didactic needs of the teachers. The teacher of the Statics asked the three-dimensional objects to accompany the statements of problems that are given to students to solve after a theoretical class. In this way, students analyze the data from the enunciate and the 3D model to better understand what is asked in the exercise.

For her part, the geometry teacher requested the 3D material for the explanation of the concepts themselves. The teacher explains the theory and the purpose of drawing process and after a first approximation to the concepts, she presents the three-dimensional object to complete the explanation.

Both teachers noticed an increase in the concentration and understanding of the students, considering also that the behavior was so cordial that classes were easier to teach.

[1] https://github.com/KhronosGroup/OpenCOLLADA/wiki/OpenCOLLADA-Tools.

In addition to the eBook developed for iPads, a complementary material was designed for students who could view 3D objects on top of printed material with their own smartphones. This option is possible with augmented reality.

Augmented reality is very appealing to students. As many products use an application called Aurasma to display information through augmented reality, numerous students already have this application installed in their smartphones.

Aurasma allowed us to use the same 3D files that we had embedded into the eBook to upload them to their app. With this advantage, it was possible to multiply the benefit of the eBook, obtaining two equally attractive and educational products, developed with the same work effort.

Augmented reality (AR) consists of having a printed image that functions as a trigger for an action. In our case, the desired action is that a 3D object could appear superimposed over the printed image through a smartphone. The printed image acts as a recognition pattern for the AR app installed on the smartphone, which in our case is Aurasma.

The process for developing an AR product involves two elements: the action trigger image and the 3D object that will appear above it.

The images that will act as triggers must have a certain singularity that allows the application to distinguish them among many others. This trigger is uploaded to the Aurasma online application where it is associated with the element that will appear by augmented reality. In our case, that element is the .dae file that we embedded into the eBook.

In the case of Aurasma, .dae files cannot be uploaded alone as in iBooks Author. Each object is required to be uploaded as a compressed .tar file containing: the .dae file, the .jpg images used to map it and a “thumbnail.png” file of exactly 256×256 pixels in dimension which can be, i.e., the logo of the project.

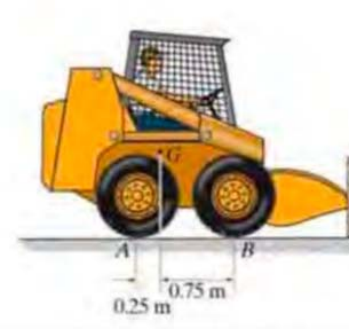
We placed the triggers along with the printed exercises that were given to the students for their homework. In this way, homework became a source of expectation and stopped being a reason for stress.

4. Implications/Discussion

The eBook developed for the subject of Statics has been used for 3 years with undergraduate students of mechanical engineering. It is installed on the iPads that are part of classroom equipment. This type of classroom is equipped with 30 iPads. They also have blackboards that have technological attributes that facilitate the taking of notes and the saving of the exercises written on the board. While these classrooms provide a modern environment to undergraduate subjects, teachers use mostly commercial apps. Our project was really the first product developed for these classroom types. Students have responded very favorably to the eBook and have expressed in polls their wishes for having more educational texts like this.

In the case of Descriptive Geometry, it was impossible to impart the subject in this type of classrooms because students require larger tables to draw. The problem was solved by projecting directly from the teacher´s iPad. Despite this drawback, students of geometry have shown more interest than students of Statics. They are more willing to participate and rotate the three-dimensional figures themselves. Their comprehension is immediate and their interest in the class is very different from what students showed before starting to use the eBook. This semester is the first in which the descriptive geometry eBook has been used and undoubtedly has been a very useful tool for the teacher.

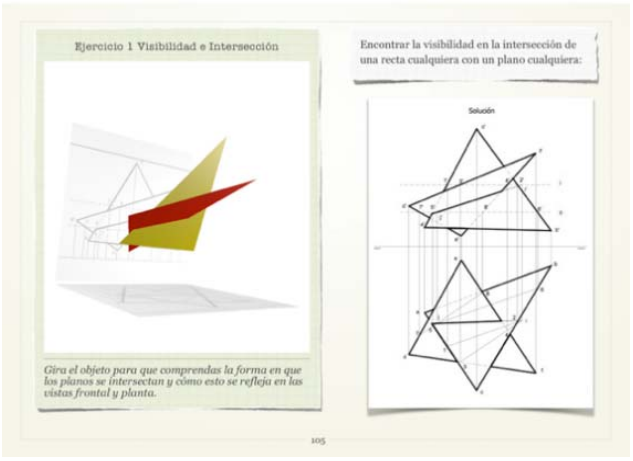
So far, teachers have not claimed to use regularly the augmented reality companion which has represented more novelty and attraction than an instrument of teaching. Having this extra material is a source of satisfaction but does not seem to maintain the concentration that produces the eBook.



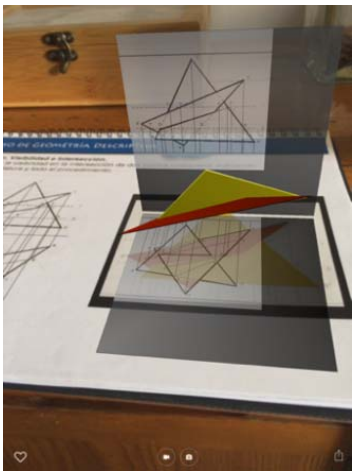
Similar exercise in printed Statics regular text books

Rotating 3D model within the eBook

Same object displaying on top of the printed version with Aurasma



Intersection exercise where the 3D object remains movable next to explanatory text.



Same exercise within Aurasma app

Results from student's surveys:

Table 1 Survey Applied to Students of Descriptive Geometry

Descriptive Geometry Students (27)	yes	no	indifferent
Do you consider it useful to have the text of the subject in eBook format for tablet?	87.5%		12.5%
Do you consider that there is an improvement in three-dimensional visualization?	100%		
Comparing it with the diagrams and projection views with which the subject is traditionally taught?	100%		
Do you consider that the manipulation of the models within the eBook, allowed you to better understand the configuration to which the exercise refers?	100%		
Would you like to have more teaching materials with rotatable 3D objects?	100%		

Table 2 Survey Applied to Students of Statics

Statics Students (120)	yes	no	indifferent
Do you consider useful to have the text of the subject in an eBook for iPad?	96%		4%
Do you consider that there is an improvement in the visualization of 3D objects compared with the traditional diagrams of the printed book?	96%		4%
Do you consider that the manipulation of the models within the eBook, allowed you to better understand what the problem asks?	80%	4%	16%
Would you like to have more teaching materials with rotatable 3D objects?	92%		8%

5. Conclusions

The incorporation of 3D rotatable objects interleaved with the text of the disciplines of Statics and Descriptive Geometry, has been decisive to achieve the understanding of the students of these two subjects.

The development of the material in eBook format with these characteristics has given the teachers of these two subjects a unique tool to be explained effectively.

From the surveys, the benefit of these materials is evident in the understanding and motivation of the students who have used them.

For now, the use of supplementary material using augmented reality has not proven its didactic effectiveness but it has been a source of attraction that increases the expectation in these two subjects previously considered unappealing for students.

The development of projects such as those described in this paper requires expertise in several areas. Obviously, knowledge of the subject from which the new educational material is planed is indispensable; CAD modeling skills are required to digitally construct three-dimensional objects as well as gain experience in assembling documents in iBook Author and Aurasma. While this knowledge can be acquired by the same person, the development time could be reduced if work is done in an interdisciplinary team. This approach has been very helpful to us.

Publishing in the Apple store is not difficult to accomplish. Special care must be taken to use only self-made material or images free of copyright. However, if the eBook has not been uploaded to the Apple Store, it can still be installed individually on students' iPads. The best option is the pre-installation in classrooms equipped with iPads.

Investing in time, equipment and interdisciplinary work to create eBooks with these and more features described in this paper, is well-timed. According to studies and trends published by Gartner, e-text technology achieved in 2 years a consolidation level and it has reached its Plateau of Productivity. The benefits of this technology have been demonstrated and accepted by the community. The tools and methodologies to create them are becoming more stable as they enter their second and third generation. A growing number of publishers are more confident with risk reduction as user acceptance increases. Gartner's trends establish that approximately 20% of the target audience of electronic texts have adopted or are adopting the technology.

In addition to eBook trends as an educational tool, the eBook market can become a rewarding option to encourage developers. The digital book market has grown every year compared to the printed book. Sales of US e-books are expected to outpace printed book sales by 2018, according to PricewaterhouseCoopers (PwC) studies published in The Economist.

Since ISATT is not a conference of technology developers but rather of academics, this paper was written with the information of the technical process in such a way as to be more useful to the community of teachers

attending the conference.

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