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Abstract	The present work can be included in a much broader research related to an improvement on the learning of structural concepts and their practical application for architecture students, and consists in identifying significant variables to predict the effect of different teaching practices using an academic analytics approach. This work gathers data from surveys answered by architecture students – from La Salle Architecture School in Barcelona - to confirm the hypothesis that motivation is a key aspect to focus on. The results confirm it, and configure the working basis to check the efficiency of the teaching practices to be analyzed next academic years and for defining a predictive model on structural learning for architectural students.

Keywords (separated by '-')	Learning analytics - Structures for architecture students - Architecture studies - Learning indicators

Identification of Significant Variables for the Parameterization of Structures Learning in Architecture Students

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Abstract. The present work can be included in a much broader research related to an improvement on the learning of structural concepts and their practical application for architecture students, and consists in identifying significant variables to predict the effect of different teaching practices using an academic analytics approach. This work gathers data from surveys answered by architecture students – from La Salle Architecture School in Barcelona - to confirm the hypothesis that motivation is a key aspect to focus on. The results confirm it, and configure the working basis to check the efficiency of the teaching practices to be analyzed next academic years and for defining a predictive model on structural learning for architectural students.

Keywords: Learning analytics · Structures for architecture students
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1 Introduction

This article is based on an investigation aimed at identifying - using the learning analytics [1] approach –significant variables to predict the efficiency of different teaching practices, in order to improve the learning of structural knowledge and its application in architecture students, so that a predictive model can be defined based on these variables.

As a first stage for the research, motivation of students on the structural area is being analyzed, and also students' perception about the need of a deep structural knowledge on structures to become an architect.

This article presents results from surveys carried out on students close to finishing the architecture degree on one side, and to students of 1st, 2nd, 3th and 4th course on the other side. All respondents are architecture students in ETSALS (La Salle Architecture School in Barcelona, originally: Escuela Técnica Superior de Arquitectura La Salle). The main aim pursued with this study is to support or refute the following hypotheses:

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- Students perceive that a deep knowledge in structures is not really needed to become an architect.
- Immersion in the atmosphere of schools of architecture boosts these students' perception.
- Generally, students close to finishing their studies do not know how to implement in practice their structural knowledge.
- Generally, motivation of architecture students in creative aspects is higher than in technical aspects.

On the other side, the surveys outcome is analyzed to find significant indicators that could be related to the representative values of the aspects that are intended to be improved, mainly the degree of learning and the degree of implementation of knowledge.

2 Context: Architecture and Structures

Even though architecture is broadly defined as a synthesis of arts and sciences from ancient times to the present [2–5], the huge amount and complexity of knowledge and competences needed has led most of the architects to specialization.

Today, architects have different professional attributions in each country, and that has led to different teaching approaches and school curricula, especially on competences required on technical subjects. Most European countries do not require deep structural knowledge to architecture students, for they have not professional attributions, while in other countries, like Spain, architects are considered to be the last responsible of building structures [6] and this professional attribution is automatically recognized when architect's title is obtained.

Even though these differences exist, European Directive 2005/36/CE [7] establishes automatic recognition of the Architect title in all EU countries, with the only condition of the possession of an Architecture title obtained in any state member of the EU, with no mention of the difference in professional attributions for each state. That leads to the fact than the same title has different professional attributions depending on the state where architecture is practiced, although titles come from diverse architecture training programs where technical aspects are treated differently.

2.1 Structures Subjects in the Spanish System

Spanish architecture study programs include a complete training in structures – design and calculation, in coherence with architectural concept, and execution surveying -, provided that architects are responsible for building structures, according to current regulations [8, 9]. With some difference between the different architecture schools, all curricula include subjects on mathematics and physics, on resistance of materials and on application of current structural codes in Spain, mainly the Building Technical Code, the Concrete Structural Code and the Steel Structural Code.

2.2 Structures Subjects in La Salle

The ETSALS was founded in 1997. The following subjects related to the structural area have been always included in the studies programs: mathematics, physics, introduction to structures, concrete and steel structures, and geotechnics and foundations. All these subjects can be found in the current syllabus [10] that meets the requirements according the Bologna process.

Currently, two study programs are mainly ongoing in ETSALS. Architecture degree is developed in five academic years in both programs. Structures area subjects are: Mathematics, Physics (1^{st} year), Introduction to Structures (2^{nd} year), Concrete and Steel Structures (3^{rd} year) and Geotechnics and Foundations (4^{th} year). Last academic program approved, dated in 2015, of 300 ECTS (European Credit Transfer and Accumulation System), requires to be completed with a Master's course of one academic year and 60 ECTS, that includes the Applied Structures subject.

Structural knowledge acquired is supposed to be applied in other subjects included in other areas, mainly in Construction (3^{rd}, 4^{th} and 5^{th} years) and Projects (1^{st} to 5^{th} years), and evidently in the Final Degree Project (FDP).

2.3 Assessing Training: Learning Analytics

Assessing training is always a difficult task, since it is closely connected to the context where (formal, non-formal and informal) training to be assessed has taken place and to the type of assessment approach that has been used. Generally, in the literature on training evaluation, two major theoretical approaches can be found: evaluation training and effectiveness training. The former is based on the evaluation of learning outcomes achieved at the end of training, which is based on the effectiveness of training that was provided. In the former approach, objectives, content and design of training become the object of evaluation; in the latter approach, however, the training process is examined in all its stages (pre, ongoing and post) considering the variables that might have influenced the effectiveness of training activities [11].

Assessment supports and fosters the quality development of an education and training system because it:

- Identifies the strengths and weaknesses of an education and training system and actions
- Observes and analyses how resources are used
- Involves and empowers the stakeholders engaged in the training system and actions
- Ensures that a change has indeed occurred with effects on the institutional and social context
- Allows to identify critical issues in a primary phase using Pre and Profile tests, and using mixed methods (combining quantitative and qualitative approaches) for a better interpretation of the results [12].

When we try to incorporate new educational methods, we need to incorporate them into teaching in a controlled manner; there are some risks that need to be controlled before one can improve not only the curriculum but also student skills and knowledge.

For example, in the case of new technologies, the professor must be trained and capable of providing full-time support to students: he or she must be capable of offering a good and precise explanation of the practice and methodology, must correctly select the applications, and must provide clear final objectives. Previous studies describe "critical mistakes" in the implementation of these types of methods, mistakes that can generate negative perceptions among the students and which need to be avoided [13].

For all these reasons, it is necessary to develop educational decision support systems, in order to improve technical education. In this framework, Learning Analytics addresses the management and analysis of the educational data for the improvement of learning: "Using analytics we need to think about what we need to know and what data is most likely to tell us what we need to know" [14].

We can affirm that Learning Analytics has become the main topic of educational conferences, and it is more than a simple trend in education [15, 16]. Ferguson defined Learning Analytics as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" [17]. Related with this concept, we can find other ideas; for example, the Educational Data Mining and the Academic Analytics. The first one is concerned with developing methods for exploring the unique types of data that come from educational settings, and the second idea, Academic Analytics, is a mixture process for providing higher education institutions with the data necessary to support operational and financial decision making [18, 19].

3 Method

As already stated, several surveys have been conducted on Architecture Students at ETSALS.

On one side, students of last year were consulted some weeks before the date of their FPD presentations, and therefore, only weeks before they became architects. This survey has been conducted four times between July 2016 and May 2017. The overall sample is comprised of 131 students, which were requested to answer questions on a scale of 1 to 5 with the aim of:

– Assess students' motivation on structural topics
– Know their perception about what they know on structures and about what should be known
– Know their perception about their capacity of being responsible of structures calculations
– Know their degree of satisfaction about their knowledge and about how structures are taught.

Students' grades obtained in subjects of structures area have been incorporated to complement this information, as has been done with the number of calls needed to pass each subject, the FDP grade, and other data like the number of structures corrections during the FDP development and the work experience of the students in architecture and/or structural studios.

On the other side, different surveys have been conducted in first weeks of the academic year 2017/2018 to undergraduate students of 1st, 2nd, 3th and 4th year. The total number of samples is 197: 55 from 1st year, 52 from 2nd year, 51 from 3rd year and 39 from 4th year students. These students were also asked to answer on a scale of 1 to 5 questions that search to evaluate the same three aspects described and to identify when significant changes take place.

Correlations between data obtained from surveys have been analyzed, especially those useful to parameterize the degree of knowledge of structures and the degree of application of this knowledge.

4 Results

This section summarizes the data analysis obtained from surveys. The numerical results presented here are the average of the answers on a scale of 1 to 5. Correlations are shown in percentage, according to Pearson correlation coefficient. Results are arranged according to the four hypotheses to check as described in the introduction.

4.1 Students' Perception About the Degree of Structural Knowledge Needed for Architects

Survey responses confirm the first hypothesis, that students perceive that a deep knowledge in structures is not really needed to become an architect. This is in contradiction with Spanish professional attributions that set architects responsible of building structures.

FDP students admit a low degree of structural knowledge, while consider not necessary to improve it. So, the average answer when requested about their capability of calculating buildings is 2.77, and 3.3 is the average score about their perception about pre-dimensioning capabilities. The students consider themselves not able to be responsible of building calculations (scoring an average of 2.43). Note that all FDP students consulted obtained the Architecture title some weeks after the date of the survey.

Even with better scores, students are critical of their degree of learning and of how structures are taught in ETSALS, as can be deducted from the answers to questions, i.e. 'if they think if they have enough structural knowledge to become architects' (average score is 3.5), if they are satisfied with what they have learnt (3.4) and the degree of satisfaction about how structures are taught (3.6).

We find especially significant that even students who answer with 4 or 5 when asked about if their structural knowledge is enough to be architects, admit not to have enough knowledge to calculate structures (scoring 2.8 and 3.6), not to be capable of being responsible of structures (averages of 2.6 and 2.75), and are the students who score lowest when asked about considering the idea of working in structures (1.8, close to the average of 1.9 got from all responses).

FDP students score with an average of 3.75 their interest in broadening structural knowledge, with 3.4 the need of deepening in it in undergraduate programs, and with 3.2 the idea of deepening it in master's programs. In this vein, an average score of 3.5 is obtained when asked for the idea of strengthening the teaching of applying structural knowledge in projects design, and 2.9 is the average answer to if it was good a more demanding assessment on structures subjects. 3.45 is the average score when asked if structural skills of architects should be improved.

It is significant that students who are more likely to work professionally in structures score higher when consulted about the need of improving architects' skills in structures. This need is also more perceived by the students that are more satisfied with their knowledge and with how structures are taught. It could be said that students who are more interested in structures think that architects' structural skills should improve.

Another interesting finding is the lack of relationship between the grade obtained in the FDP and the average grade of structures subjects got during the undergraduate studies. Correlation between these two variables is just 12%. Answers of the five students who got the maximum FDP grade of 10/10 are in line with the hypothesis being checked that students perceive that architects do not need to have deep structural knowledge. They score their ability to calculate with 2.4 (average is 2.8), their capability of being responsible of calculations with 1.5 (average is 2.4) and they are not thinking of working professionally in structures (1.6 when average is 1.9). They think it is not necessary to deepen structural knowledge (2.4 when average is 3.4) and are the ones who least want to improve their knowledge (3.2 in front of the average score of 3.8).

4.2 Influence of the Atmosphere of the School of Architecture in This Perception

Students are aware that many architects do not know how to calculate structures, and this awareness takes place in the first academic year. That can be deducted from the answers of undergraduate students when asked about it. At the beginning of the 2nd year, the average answer score is 3.2, similar to the score got from 3rd and 4th year students, while the students who begin 1st year mark it with an average of 4.2. Therefore, this change of perception occurs in one academic year, which is also reflected when asked if they think they will know how to calculate when they finish the degree, going from 4.55 (1st year students) to 3.7 (3rd and 4th year). The hypothesis seems confirmed, as this perception changes significantly in only one academic year.

The fact that the grade of the FPD has virtually no relation to the grades obtained in the subjects of the area of structures increases this perception that structures are not an essential part of the knowledge necessary to be an architect.

4.3 Perception of the Students About Their Capacity for Practical Application of the Knowledge of Structures

The answers of the students on this perception give rise to results that are thought to be different from those that teachers would have. It would therefore be necessary to contrast with the perception of teachers, to confirm whether both perceptions are similar or, as we suspect, differ. Teachers of subjects on structures at ETSALS have an average teaching experience of more than 15 years, and an average professional experience in structures of more than 25 years.

FDP students consulted think they are able to adequately select the structural typology for their buildings (average score of 4.1 for residential buildings and 3.8 for public buildings), which contradicts the teachers' experience. As has been said, the perception of the application of knowledge is low when asked if they are able to pre-dimension (3.4) and calculate (2.8) their structures.

When the FDP students are asked if they have applied the knowledge of structures to the workshops and projects they respond with a 3.7, and when they are consulted about the application in the FDP they score with a 4.0.

In the case of similar questions, students who begin 3rd year score 2.9 on being consulted about whether they apply the knowledge to projects and workshop, while in 4th grade this value rises to 3.8. 3rd year students respond with 2.82 when consulted about whether they know how to pre-dimension, and those of 4th respond with a 3.36.

As can be seen, values are generally low, and it would be confirmed (in the absence of contrasting data obtained from teachers) that there is a considerable margin for improvement.

4.4 Motivation of Students in Technical and Structural Aspects of Architecture

Responses reveal a lack of motivation in the technical field in general, and in structures in particular, as can be deducted from different answers: in students from 1st to 4th year, the motivation for the technical part (3.85 on average) is always below the motivation for the creative side (4.55 on average). FDP students declare that they do not have interest in working professionally in structures (1.9 on average), a score much lower than that declared by students from 1st to 4th year when asked on the interest in working in a technical branch (3.24) and even lower than the same students when asked if they would like to work in a creative field (4.5).

In addition, students who have not yet started studying any subject of structures perceive that structural knowledge is not completely necessary for architects and believe that structural subjects will be difficult for them. The finding of this predetermined thinking is found in the following answers: before taking any subject on structures, students think that they will not like them very much (score of 3.6) and that those subjects will be difficult to pass (3.4 of average score where 1 is easy to pass and 5 is difficult to pass). Later, when they have already taken one or two subjects of structures, they confirm that they do not like them (3.5 on average) and they find them even more difficult than they expected (2.85).

4.5 Other Significant Relationships Between Data

The relationship between data has been analyzed to identify variables that significantly affect students' perceptions.

It has been found that there is no significant correlation (16%) between the average grade in structural subjects and the perception of the students that they know enough. It is remarkable the fact that the average grade in structural subjects makes no difference on the score to the question about knowing how to calculate (around 2.8 on average for all the studied grade ranges). Students who have the best average grade of structures score lower than the rest on their ability to be responsible for the structures of the buildings. Finally, the 5 people who achieved a higher than average grade in structures stand out to be poorly satisfied with the acquired knowledge (2.3 when the average is 3.4), and are also unhappy with how structures are taught (3 when the average is 3.6). At the same time, they are the ones who most believe that the level of structures of architects needs to be improved (4.2 when the average is 3.5).

5 Conclusions and Future Lines

The following hypotheses are considered to been proven:

– Architecture students have the perception that a deep knowledge in structures is not really necessary to be an architect.
– Immersion in the atmosphere of an architecture school boosts this vision.
– In general, students close to finishing the degree of architecture do not know how to apply the structural knowledge acquired in practice.
– In general, the motivation of architecture students is lower in the technical aspects than in the creative ones.

In order to achieve the learning objectives, and to parameterize the results as far as possible, identifying significant indicators, the following future lines of action are considered:

– Check if the students' motivation improves when focusing structural subjects on practical application of structural knowledge.
– Check if there is any improvement in results when motivation improves.
– Check if a change in the perception that structural subjects are difficult will result in an improvement of the results.

For this last point, as shown in various studies such as those collected by Ken Bain [20], perceptions of students may have an influence on the results they obtain. It may well be that students' performance decreases if they perceive that they do not need to know about structures and that it will be difficult to achieve a satisfactory grade in structural subjects.

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