Student and Staff Perceptions of Key Aspects of Computer Science Engineering Capstone Projects

J. J. Olarte; C. Domínguez; A. Jaime; F. J. García-Izquierdo

IEEE Transactions on Education

Year: 2016, Volume: 59, Issue: 1

Pages: 45 - 51, DOI: 10.1109/TE.2015.2427118

IEEE Journals & Magazines

# Student and Staff Perceptions of Key Aspects of Computer Science Engineering Capstone Projects

Juan José Olarte, César Domínguez, Arturo Jaime, and Francisco José García-Izquierdo

*Abstract*— During the development of capstone projects, a student uses knowledge and skills acquired throughout the degree program to create a product or render a service technical in nature. An advisor is assigned to guide the student and supervise the work, and a committee assesses the project. This study aims to compare student and staff perceptions of key aspects (i.e. project characteristics, student competencies, advisor involvement, and student perceived learning) involved in the process of completing a project of this kind. The primary finding of this study is that the expectations of students differ greatly from the expectations of staff. In particular, students tend to have a better opinion of their project, their own competencies, and the supervision received as compared to the staff. Regarding the student's perceived learning, not all aspects examined are consistent with the grade obtained and the satisfaction experienced. This discordance suggests the need for a more effective method to communicate the actual expectations more clearly to students and share them with the staff.

***Index Terms*— Capstone project, computer science engineering, student and staff perceptions.**

## I. INTRODUCTION

COMPUTER science engineering degree programs usually include a capstone project in which students create a software product or render a technical service [2], [6]. While conducting the project, students use knowledge and skills they have acquired throughout the degree program. Given that this represents a much larger task than those completed until this point, it poses a personal organization challenge for the student. Developing a capstone project usually involves locating information, writing technical reports, creating some kind of prototype, preparing an oral presentation, and organizing meetings. The experience is extremely useful in preparing students for professional issues they will most likely encounter in the future [16], [21], [26]. A capstone project usually takes a semester or a full school year depending on the stipulations of the particular degree.

Capstone projects studied herein can be described by using the framework proposed by Clear et al. [6], which facilitates comparison to other research. Each capstone project is conceived of as a subject without classes, completed during the last year of the degree program. It requires an investment of approximately 600 hours, and typically includes analyzing a computer problem, designing and implementing a solution, and writing the necessary documentation. Each student performs individually the project and an instructor is assigned as the advisor who guides and supervises the student's work. The project may be proposed by the student, the advisor or the company. In any case, a departmental committee evaluates the suitability of each project before it is assigned. Upon completion of the project, the student must submit a portfolio describing their solution and process. The project is then presented orally in a public forum before a three-instructor committee responsible for grading. The grading criteria are public and the grade breaks down as follows: technical solution (40%), quality of the written report (30%), project management (20%), and presentation and oral defense (10%).

The objective of this study is to examine the viewpoints on capstone project development of the three main actors: student, advisor, and evaluation committee; and identify interesting differences or correlations so as to derive lessons and identify elements for reflection which may be useful for improving project supervision. Four aspects recognized by various authors as key elements of capstone projects are analyzed herein [21], [19]: *project characteristics*, *student competence*, *advisor involvement,* and *boosting learning* during project development. The main hypothesis is that staff and students have very different perceptions of the first three key elements mentioned. This hypothesis is verified by gathering data on the perception of students, advisors, and the committees, for a given set of projects, through surveys designed for this purpose. Regarding the enhancement of learning, the hypothesis is that according to the student's point of view, not all skills utilized during the project have the same weight on the grade. The study also identifies the main types of projects, students, and supervision styles. Once the compiled projects were classified according to these three issues, the next task was to search for interesting differences in the available data in order to delve further into the objective of this study.

## II. LITERATURE REVIEW

Among the elements recognized as key factors in the realization of capstone projects, let us highlight the

Manuscript received xx. This work was supported in part by University of La Rioja, Project PROFAI 13/13

Authors are with Dept. Matemáticas y Computación, Universidad de La Rioja. Ed. Vives, Ulloa s/n, E-26004 Logroño, Spain (e-mails:{jjolarte, cesar.dominguez, arturo.jaime, francisco.garcia}@unirioja.es

*characteristics of the project* [19], [21], [22]. Scope can vary greatly from project to project; since they can be conducted in an academic or business context. Projects may sometimes require the use of the latest technologies, while other projects only need conventional technologies. In some cases the range of technologies required in the project can be vast, while in others a few technologies may be sufficient [21]. Although the project is normally an individual effort, it can also be designed as an individual contribution to a team effort [14], [6].

Another component of a capstone project is the student who performs it. The advisor should have firsthand knowledge of the student's views and aspirations throughout the different phases of the project [12] and adapt their supervision in accordance with *the competencies and characteristics of the student* [11].

Project supervision involves a number of tasks that can be time-consuming: guidance of management tasks, technical assistance, review of technical documents... The advisor must decide to which tasks he will devote more attention and what his *degree of involvement* will be [7], [21]. The advisor may play several simultaneous roles, among them: monitor, mentor, sponsor, administrator, and confidant [6], [16]. The advisor's level of involvement in the tasks usually varies according to the stage of development and is usually greater during the beginning phases of the project [6].

It is also important to find ways to *boost learning* [21] in the completion of the project tasks. The advisor must tackle the problem of how to structure the process in order to ensure an effective learning environment without compromising the independence or open-ended nature of the student's experience. Students should learn to address problems, analyze them and attempt to resolve them on their own [21]. The key is finding the adequate type of supervision and the right level of guidance [19], [14]. The type of assessment mode can also enhance learning in some aspects more than others. Many formats for project evaluation are proposed [12]. Some authors remark on the notable lack of consensus regarding what the key issues are in project evaluation, as well as some students' perception of unfairness [15]. James *et al*. [14] suggest that it is important for both the advisor and the student to agree on these key issues regarding evaluation. Orsmond *et al*. [24] observe that the students were aware of what they needed to do in order to pass the evaluation, but they were not clear on what they needed to do to develop into professionals.

Goodwin and Mann [13] conducted a qualitative case study based on a unique project comparing the views of students, academics, clients, and industry advisors about the project characteristics in a computer engineering degree. All respondents were in agreement regarding the utility of the developed product. However, opinions diverged regarding the value of process and product quality. The authors observed that these discrepancies may reflect differences in each party's understanding of the project and its results.

Chan [5] performed a comparative study between the marks proposed by advisors and evaluation committees on capstone projects in a computer engineering degree. Although the ratings were correlated, discrepancies did arise given the excessively low marks assigned by the committee.

Some studies of undergraduate projects in biology compare the views of students and advisors. E.g., Orsmond *et al*. [24] conducted a quantitative study about the impact of the project work in the enhancement of professional development, and project assessment grade. They found significant agreement between students and staff regarding the attributes of assessment value. However the authors did not encounter correlations in professional development attributes. Stefani *et al*. [25] developed a qualitative study comparing the views of students and staff about the purpose of projects, and roles and responsibilities of advisors. They found a clear amount of discordance between staff and student conceptions of the projects' purposes. They also observed that expectations between students and supervisors are in dire need of clarification. In other areas such as business, a comparative study of the perceptions of students and advisors is suggested to be of great interest [10].

Apparently, no quantitative study of engineering capstone projects have been conducted comparing the views of the main actors: students, advisors, and committees; on four key elements of capstone projects: project characteristics, student competence, advisor involvement, and boosting learning. The present study tries to address this lack of research.

## III. METHOD

### A. *Sample*

The sample was obtained from the capstone projects completed by undergraduate computer science engineering students at the University of La Rioja (20 advisors supervising 75 student projects completed between 2012 and 2013). For each project, questionnaires were collected from the student, the advisor and the evaluation committee. These three questionnaires were successfully collected for 57 projects.

### B. *Research Design*

Three questionnaires were designed for: the student, the advisor, and the committee that evaluates the project; available at http://www.unirioja.es/cu/cedomin/questionnaires.pdf. The initial pool of items for the survey was determined by reviewing the literature on supervising undergraduate projects and dissertations [6], [7], [16], [21], [26]. To avoid omitting important aspects, and to ensure that the items would be interpreted as intended, several university professors with experience in capstone supervision were asked to review the set of items, and their suggestions were incorporated. Some of the same items are included in several of these questionnaires. This fact allows us to compare the different perspectives.

There is a block for each of the key factors mentioned above. The first block refers to project characteristics such as scope, complexity, or technological novelty. The student competencies block includes questions about management, technology, or writing competencies. The advisor involvement block reflects the involvement of the advisor in facets such as technical aspects, meeting organization, or reviewing of documents. Involvement is understood as the advisor's level of intensity engaging in the tasks of guiding and supervising. This

TABLE I
MEANS (STANDARD DEVIATIONS) VIEWS OF PROJECT CHARACTERISTICS

| Aspect (1-4) | Student | Committee | Advisor | $\aleph^{2\,a}$ (df) | Bonferroni[b] |
|---|---|---|---|---|---|
| Scope | 2.93 (0.68) | 2.72 (0.75) | 2.67 (0.74) | 7.11 (2)* | St>Co, Ad |
| Complexity | 2.93 (0.75) | 2.68 (0.83) | 2.47 (0.73) | 20.46 (2)*** | St>Co, Ad |
| Technolog. novelty | 2.86 (0.93) | 2.40 (0.94) | 2.33 (0.93) | 15.42 (2)*** | St>Co, Ad |
| Product usefulness | 3.51 (0.78) | 3.19 (0.89) | 2.93 (0.90) | 20.67 (2)*** | St>Co, Ad |
| Need for training | 3.18 (0.83) | 2.98 (0.95) | 3.04 (0.89) | 2.24 (2) | |

[a]Friedman test, *p<0.05, ***p<0.001, [b]Differences after Bonferroni correction

block also includes an item to assess the adequacy of his supervision for the project. Finally, the last block contains information about the level of learning perceived by students in areas such as technology, methodology, or project management. Since the questionnaire is completed after the student is informed of the grade awarded by the committee, this block also contains a question on student satisfaction with the grade obtained. Except some questions about objective data on the student and the project developed the questionnaires contain items on a Likert scale of 1-4 labeled from "strongly disagree" to "strongly agree". There is no middle option, creating a forced-choice method.

For each project, the student and the advisor complete their questionnaires in private, and place inside a sealed anonymous envelope. The committee collects the advisor's and student's envelopes and puts them together with their own questionnaire into another sealed envelope.

Statistical analysis was performed using the SPSS v.19 statistical package. Whenever possible (when the assumptions were verified) parametric tests were used. Otherwise, corresponding non-parametric tests were utilized. The effect size was calculated and interpreted following the criteria suggested by Ellis [8].

## IV. RESULTS AND DISCUSSION

### A. *Project characteristics*

Table I lists the results (means and standard deviations) of the students, advisors, and committees perspectives regarding five aspects of the project: scope, complexity, technological novelty, product usefulness, and the need for training. Significant differences can be observed between student view and both advisor and committee views in all aspects, except for need for training. The opinion of the students is always the most optimistic. The differences between advisor and committee are not significant, although the views of the committee are more positive except regarding need for training. The reason for these differences may be due in part to the fact that students have fewer points of references with which to compare their work, while their advisors have a broader perspective. Marin *et al.* [21] suggest that students review some design projects similar to capstone projects before commencing their own. The Dunning-Kruger effect [18] could also explain this situation. According to these authors, people tend to overestimate their abilities in many social and intellectual domains. Their incompetence robs them of the metacognitive ability to realize

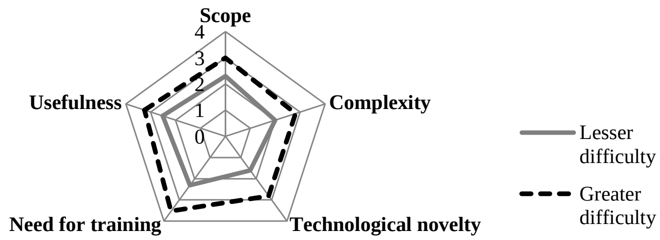


Fig 1. Advisor perception for the two types of projects identified

TABLE II
DISTRIBUTION OF THE PROJECTS IN TWO TYPES (ACCORDING TO ADVISORS) WITH MEANS (STANDARD DEVIATIONS) FOR SOME REQUESTED DATA

| Requested data | Lesser difficulty | Greater difficulty | Statistical test |
|---|---|---|---|
| Grade (0-10) | 7.06 (1.13) | 8.61 (1.0) | U[a]=1174.0*** |
| Advisor time (1-4) | 2.70 (0.82) | 2.38 (0.98) | n.s. |
| Hours spent | 540.27 (217.78) | 629.63 (356.11) | n.s. |
| For a company (y/n) | 7/15 | 19/13 | $\aleph^{2\,b}$ =3.965* |
| N | 23 | 32 | |

[a]Mann-Whitney test, [b]Pearson $\aleph^2$ test, n.s. not significant, *p<0.05, ***p<0.001

this. Moreover, paradoxically, by improving their skills, individuals can better recognize the limitations of their own abilities. It may also be that advisor expectations are not fulfilled in a substantial number of projects. Stefani *et al.* [25] highlight that there is a strong need for clarification of expectations between students and advisors. Goodwin and Mann [13] conclude that early identification of contrasting perceptions and their subsequent clarification can improve the value of the project in terms of process, usability and product quality. Nelson *et al.* [23] note broad differences in scope and quality of the projects, while James *et al.* [14] suggest that it is the staff's role to collectively agree on the appropriate levels of academic merit. To ameliorate this situation, some institutions, including the institution examined in this study, organize review committees that take action prior the commencement of projects. Some authors [10] even advocate restricting the realization of final projects to those students who perform at higher level academically.

Abedini *et al.* [1] note that many factors can influence the instructor-student relationship and that these are in need of further study. Some of these factors are inherent to the natures of both the advisor and student, such as character, style or behavior [1]. Possible communication difficulties may also be of some influence: on one hand, the advisor must transmit his or her expectations to the student [25], and on the other hand, the student should explain to the advisor the problems encountered and the potential of the work underway. This difference in the perceptions of the project between students and advisors should impel us to reflect on how communication works and how to improve on it in future project supervisions.

The projects were also classified regarding the five issues listed in Table I. Only the data provided by advisors was utilized, because they have a broader perspective. As a result of a cluster analysis, two groups of projects were formed: those of greater and lesser difficulty. Two outlier projects were excluded.

TABLE III

COMPANY VERSUS ACADEMIC PROJECTS WITH MEANS (STANDARD DEVIATIONS) FOR SOME REQUESTED DATA

| Requested data | Company projects | Academic projects | Statistical test |
|---|---|---|---|
| Scope (1-4) | 2.92 (0.56) | 2.47 (0.82) | U[a]=260.0* |
| Complexity (1-4) | 2.69 (0,62) | 2.30 (1.02) | U[a]=267.0* |
| Utility (1-4) | 3.35 (0.63) | 2.53 (0.94) | U[a]=200.5** |
| Grade (0-10) | 8.65 (1.06) | 7.37 (1.17) | U[a]=159.0*** |
| Hours spent | 721.8 (374.6) | 478.0 (148.6) | U[a]=163.5** |

[a]Mann-Whitney test, *p<0.05, **p<0.01, ***p<0.001

TABLE IV

STUDENT & ADVISOR PERSPECTIVES REGARDING STUDENT COMPETENCIES

| Competence (1-4) | Student | Advisor | Wilcoxon | Spearman |
|---|---|---|---|---|
| Autonomy | 3.16 (0.70) | 2.88 (1.00) | Z=1.982* | ρ=0.335* |
| Management | 2.58 (0.73) | 2.23 (0.96) | Z=2.296* | ρ=0.136 |
| Technology & methodology | 3.00 (0.57) | 2.68 (0.89) | Z=2.506* | ρ=0.262* |
| Meetings & communication | 3.09 (0.69) | 2.32 (1.02) | Z=4.604*** | ρ=0.348** |
| Writing | 2.88 (0.76) | 2.46 (0.89) | Z=3.304** | ρ=0.514*** |

n.s. not significant, *p<0.05, **p<0.01, ***p<0.001

Fig. 1 shows the means for each of the five aspects mentioned above for the two types of project. Marked differences can be observed for all factors. And furthermore, some data collected by the surveys regarding several aspects for these two types of projects were analyzed; the means (s.d.) of which are presented in Table II.

Projects of greater difficulty received better grades and were created for companies in a greater proportion, with significant differences in both cases. One can also observe that projects of a lesser difficulty require more time of the advisor but, students undertaking these projects devote slightly fewer hours; however, the differences are not significant and the effect sizes are low (Cohen's d are 0.35 and 0.30, respectively). It seems logical that more complicated projects deserve better grades in general. The same result was also obtained by other studies [19]. Moreover, the results obtained here include more projects of greater difficulty. This is different from another study of undergraduate multimedia projects that indicates that students tended to choose a simple issue so as to graduate on time [22].

Table III compare company and academic projects (means and standard deviations) in regards of the scope, complexity, and utility according to the advisors, as well as the grade obtained, and the hours spent. Significant differences were found in all the aspects. Some authors also note that projects for companies often have greater scope and complexity than academic projects [17], [20]. This observation is consistent with the significantly greater proportion of company projects found among those of greater difficulty in the present study. Company projects address real world problems, thereby increasing student engagement and motivation [20], [26]. This can lead to better results and consequently, better grades.

## *B. Student competencies*

Table IV presents the points of view of both students and advisors in regards to five student competencies: autonomy (performing tasks and making decisions), management (planning, monitoring and control), technology and

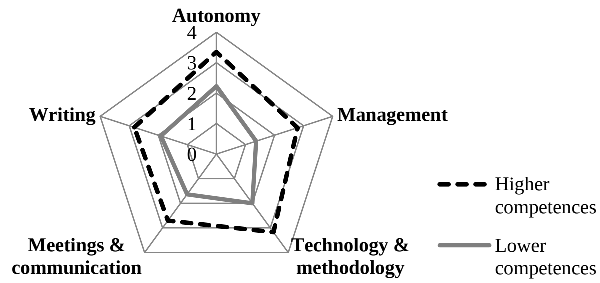


Fig 2. Advisor perception for the two types of students identified

n.s. not significant, **p<0.01, ***p<0.001

TABLE V

DISTRIBUTION OF THE STUDENTS IN TWO TYPES (ACCORDING TO ADVISORS) WITH MEANS (STANDARD DEVIATIONS) FOR SOME REQUESTED DATA

| Requested data | Lower competence | Higher competence | Statistical test |
|---|---|---|---|
| Grade (0-10) | 6.93 (1.03) | 8.63 (0.96) | U[a]=94.500*** |
| Advisor devoted time (1-4) | 2.55 (0.96) | 2.5 (0.87) | n.s. |
| Avg. grade of degree (0-10) | 6.08 (1.47) | 6.54 (0.61) | n.s. |
| Hours spent | 518.1 (159.9) | 636.9 (358.7) | n.s. |
| In a company (y/n) | 6/15 | 20/14 | $\aleph^{2\,b}$=4.767* |
| N | 22 | 34 | |
| Greater difficulty (y/n) | 8/14 | 25/7 | $\aleph^{2\,b}$ =9.567** |

[a]Mann-Whitney test, [b]Pearson $\aleph^2$ test,
n.s.not significant,*p<0.05,**p<0.01,***p<0.001

methodology, meetings and communication, and writing (ongoing documents and final report). Significant differences exist between the opinions of students and of their advisors for all competencies. The students have a more positive view of their capabilities. The most remarkable difference is found in meetings and communication. There are positive correlations between the two perspectives in all regards (significant in most cases). This finding means that both views are consistent.

As in the case of project difficulty, the advisor has a broader range of reference than the student to compare. The Dunning-Kruger effect could explain this situation as well [18]. The advisors should be aware that their opinions of student competencies are significantly worse than the opinions of the students themselves. This situation suggests that students may not consult with their advisors on important issues because they believe that their competency levels are in line with the evaluation committee's requirements. Another study did not encounter any correlation between student and advisor perceptions of the skills development during project realization [24].

Advisors should also be aware that the difference in perception is more pronounced on issues of oral and written communication. Having such a positive perception of their communication skills, students probably fail to see the need to make further efforts to transmit the project's achievements or to improve their skills in this area. Some institutions and researchers believe that university degrees should devote extensive time to this type of generic skill since discordance has been detected between the skills acquired during university studies and what is actually required in the workplace [3], [24]. Some studies point out that evaluation systems for final projects do not necessarily take into account these types of competencies

[25].

Projects were also classified according to the five student competencies of Table IV. Again, only the data from advisors was utilized. As a result of a cluster analysis, the projects were divided into two groups: students with lower and higher competencies. One outlier project was excluded. Fig. 2 shows the means for each of the five aspects mentioned above for the two types of student. In all aspects, marked differences can be observed.

Other data compiled in the surveys regarding the two types of students were analyzed: the means (s.d.) are included in Table V. The number of projects previously classified as of greater/lesser difficulty for each type of student is also included.

One can see that more competent students received better grades and carried out projects for companies in greater proportion, with significant differences in both cases (note that students can freely choose the project to develop). This finding coincides with the previous observation regarding greater difficulty projects. One can also observe that there are significant differences in the distribution of greater difficulty projects in favor of more competent students. Less competent students were also found to require similar advisor time and devote less time to the project, although the differences are not significant and the effect sizes are low (Cohen’s d equal to 0.05 and 0.43, respectively). No significant differences were found in the average grade declared for the subjects of the degree program (and the effect size is low, Cohen’s d = 0.41).

It is remarkable that a significantly greater proportion of the more competent students prefer to perform the project in a company. As mentioned above, some studies suggest that company projects may increase students’ engagement and motivation [20], [27]. Hearing about other students’ prior experiences, or the opportunity to make contacts in the real working world could attract the most competent students.

Some results seem surprising. For instance, while students with lower skills normally require greater dedication from the advisors [25], [11], the results obtained for both types of students are very similar. It is also surprising that the average grade declared for the subjects of the degree program is so similar. In this sense, some authors suggest that the competencies important for the realization of projects are different from those necessary for studying other subjects [14], [16], [21]. Lan and Ginige [19] observe significant correlations between average degree program grades and project grades on one hand, and with project achievements on the other hand. In any case, further research would be useful to clarify these issues.

### *C. Advisor involvement*

Table VI presents the results of the perspectives of students and advisors regarding the level of advisor involvement. It includes the main supervision factors [7]: technology, arrangements (planning and initial decision making), keep alive (maintaining the student active in the project), execution (support for non-technical problems), meetings (organization and holding), management (monitoring and control), and reports. The table also includes an overall measurement of involvement and the difference between the actual and the appropriate level of involvement for the project.

There are very significant differences between the level of supervision perceived by the student and by the advisor. The student's opinion is always more positive. There are also positive correlations (sometimes significant) between both views on all aspects, which means that both views are consistent. These results demonstrate that students feel better supervised than their advisors believe. But it should be noted that, according to another aforementioned results, students also have a significantly better opinion of their own competencies as compared to advisors. With this discrepancy in mind, it is logical that students would regard their advisor to be very involved, as compared to their perception of their own needs. As indicated above, this finding could be a consequence of the Dunning-Kruger effect [18]. Consequently, it is also reasonable to suppose that the advisor considers that his involvement to be smaller, because he perceives a less competent student who would be in need of more guidance. This difference may also be due to the interest of advisors in monitoring a project by providing a sufficient level of support so as to avoid the student feeling unattended, but also because of their interest in allowing the student the opportunity to acquire professional competencies on their own [14], [19].

The study of Stefani *et al.* [25] reveals a large range in the need for help expressed by the students. While 40% believe that they should receive quite a lot or a lot of help, 53% would only ask for help when needed. Stefani *et al.* also note that many advisors would like to have some guidance regarding the most appropriate level of involvement.

The projects were also classified according to the type of supervision. To do so, the first seven factors listed in Table VI were considered. Again, only the data provided by advisors was used, because they have a broader perspective on project supervision. For this classification, a discriminant function analysis was performed using the clusters obtained in a previous work [7]. And as a result, the projects are classified into three styles: “Student alone”, “Execution focused”, and “Global supervision”. Fig. 3 shows the means for each of the seven aspects mentioned above regarding the three types of supervision. Marked differences between the styles "Student alone" and "Global supervision" can be observed. The style "Execution focused" on the other hand, tends to assume an intermediate position in more than half of the factors. Hence, these styles roughly correspond to low, intermediate, and high supervision.

Some other data collected in the surveys regarding these

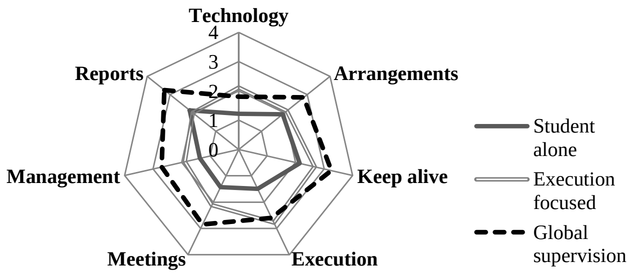


Fig 3. Advisor implication perception for three supervision styles

TABLE VII
DISTRIBUTION OF THE PROJECTS ACCORDING TO THE THREE TYPES OF SUPERVISION (AS PERCEIVED BY THE ADVISORS) WITH MEANS (STANDARD DEVIATIONS) FOR SOME REQUESTED DATA

| Requested data | Student alone | Execution focused | Global supervision | Statistical test |
|---|---|---|---|---|
| Grade (0-10) | 8.11 (1.36) | 7.61 (0.99) | 7.87 (1.30) | n.s. |
| Advisor time (1-4) | 2.04 (0.84) | 2.67 (0.50) | 3.20 (0.79) | $F^a$=13.822*** |
| Global involvem. (1-4) | 1.79 (0.62) | 2.50 (0.53) | 2.86 (0.64) | $\aleph^{2\,b}$=24.715*** |
| Actual vs appropr.(1-4) | 2.03 (1.02) | 1.90 (0.57) | 2.02 (0.88) | n.s. |
| Hours spent | 653 (390) | 463 (115) | 561 (164) | n.s. |
| Company (y/n) | 16/12 | 2/7 | 8/11 | n.s. |
| N | 28 | 9 | 20 | |
| Greater difficulty (y/n) | 18/10 | 5/3 | 9/10 | n.s. |
| More competent (y/n) | 18/10 | 4/5 | 12/7 | n.s. |

[a]ANOVA test, [b]Kruskal-Wallis test, n.s. not significant, *** p<0.001

three types of supervision was also analyzed: the means (s.d.) are included in Table VII. The number of projects previously classified as of greater/lesser difficulty, and the number of students classified as more/less competent was also analyzed according to each type of supervision. The only significant differences comparing the three styles arise in time of the advisor and advisor global involvement. No additional mean differences were found when the latter two types of supervision were compared with each other. The differences found are consistent with the supervision styles. The style "Student alone" reflects the lowest amount of time and advisor involvement, while the style "Global supervision" reflects the highest data.

Some of the results in this table merit special attention and four issues are highlighted herein. The first issue is that no differences regarding the difficulty of the project or the student's competence were found among the three supervision styles. Let us recall that according to some authors less competent students often require more dedication from the advisor [25], [11]. This result could mean that, in this case, the type of supervision could be more related to the personality of the advisor than to the type of student. James *et al.* [14] suggest that the supervisor should be involved in the assignment of projects so that they are suitable for the type of student. Clearly, extremely complex projects should not be assigned to less capable students and vice versa. The second issue is that the style used has no effect on the perception of the adequacy of involvement (difference between actual vs. appropriate involvement), which is low (around 2) in all cases. The third issue is that there are no significant differences regarding projects for companies. It seems logical that advisors would

TABLE VIII
CORRELATIONS BETWEEN STUDENT LEARNING AND GRADE

| Learning aspect (1-4) or grade (0-10) | Global learning | Grade | Grade satisfaction |
|---|---|---|---|
| Technology | 0.654*** | 0.464*** | 0.403** |
| Methodology | 0.461*** | 0.149 | 0.102 |
| Management | 0.313* | 0.225 | 0.094 |
| Professional skills | 0.473*** | 0.390** | 0.278* |
| Global learning | | 0.489*** | 0.366** |
| Grade | | | 0.489*** |

Spearman Rho correlation test, *p<0.05, **p<0.01, ***p<0.001

delegate part of project activities to companies (such as those related to technology or management). This would imply a significantly greater proportion of enterprise projects in the supervision style "Student alone", but the obtained results do not support this supposition. Finally, students supervised in the style "Student alone", which requires less time of the advisor, spent more hours on the project, but not to a significant degree. However, some effect sizes (Cohen's d), such as those found between the style "execution focused" and the styles "student alone" and "overall supervision" are medium-high size (0.66 and 0.69 respectively). Further research would be necessary to clarify these interesting questions.

### D. *Correlations with student learning*

And lastly, students' perception of what they learned developing the project is analyzed. Table VIII presents the correlations among four learning aspects (and the grade obtained) with global learning (student learning from the project [13], including the four aforementioned aspects), grade obtained, and student satisfaction with the grade. Significant correlations appear between each of the aspects of learning and global learning. In the case of project management, the significance level is lower. The grade obtained is significantly correlated with global learning and learning in technological and professional aspects. In the other two areas the correlation is positive, but not significant. A similar situation occurs with student satisfaction with the grade obtained. There is also a strong correlation between the grade obtained and student satisfaction with it.

From the above results, it should be noted that project management and methodology have lower correlations than the rest of aspects of learning, for the three comparison sources (global learning, grade, and grade satisfaction). Management and methodology are related to the process of project development. Perhaps the student, or the evaluation committee, or the advisor, are assigning more importance to the outcome, the product, or technology. In some institutions, projects are assessed mainly by the product obtained [4], and the format for evaluating the project may affect student interest in the process. James *et al*. [14] warn that some students are averse to performing activities that are not reflected in a significant portion of the grade. The development process (management, methodology) is very important for the success of the project, product quality, and student learning [4], [26]. This fact is reflected in some comments from students gathered in [13]. Orsmond *et al.* [24] found no correlations between perceptions of advisors and students regarding the importance of the project for professional training. In this sense, some authors propose endowing process with greater importance in the evaluation [15], [9]. In the case studied herein, the rubric for evaluating projects assigns a minimum of 20% of the grade to the process.

## V. Conclusions and Future Work

This work is a quantitative study on computer science engineering capstone projects comparing the viewpoints of the main actors: advisors, evaluation committees, and students; regarding four key elements: the type of project, student competencies, advisor involvement, and student perceived learning. The main contribution of this work is to quantify discrepancies among the actors on the key elements. Some authors previously suggested some of these discrepancies, although using informal methods or concerning particular aspects related to the aforementioned four key elements (i.e. marks or students skills developed).

The first result obtained is that students have a better opinion of their projects than their advisors. The same is true regarding student perception of their own abilities (the most remarkable being meetings and communication), and the supervision received. Students also have more optimistic opinions of their project than the committee. These findings seem to support the main hypothesis: staff and students have very different perceptions of the project completed, student competencies, and advisor involvement. These results impel one to search for a more effective method to convey to students what the real expectations are concerning all the above-mentioned aspects.

Regarding perceived learning, only certain aspects (technology and professional skills) are noted to be consistent with the grade obtained and grade satisfaction. These results provide support for the second hypothesis: not all skills put into practice during the project have the same weight on the grade, according to the student's point of view. This finding suggests that students perceived the product obtained to have a greater influence on the grade than the process followed to obtain the product. Henceforth, a revision of the assessment method and the interpretation of it are necessary. It may also be that students' opinions of the process does not meet staff expectations, in which case a solution similar to that proposed for the previous discrepancy must be found.

In addition to the above results, some other surprising findings arose during this study that merit further study. For example, the most competent students prefer to do company projects (which usually increase engagement and motivation); this type of project entailed greater difficulty in greater proportion. Furthermore, the only feature studied herein that is clearly related to the type of supervision employed is time spent; and this appears to be independent of other important aspects, such as project difficulty or type of student.

These results could possibly be applied, to capstone projects of similar characteristics in other degree programs. The most desirable situation would be to conduct research in several fields. New studies should also be conducted to confirm results obtained with larger samples.

## References


[1] M. Abedini, A. Abassi, F. Mortazavi, & B. Bijari. (2013). The effective factors on the communication between students and faculty members from student's prospective. Procedia Soc. Behav. Sci. 83(4), 94-98.

[2] ACM/IEEE-CS, Computer Science Curricula 2013.

[3] A. S. Blicblau & K. Dini. (2012). Intervention in engineering students' final year capstone research projects to enhance their written, oral and presentation skills. Int. J. Eng. Pedag. 2(3); 11-18.

[4] P. Brazier. (1998). Process and product in a software engineering course: simulating the real world. In Frontiers in Education Conference, 1998. FIE'98. 28th Annual (Vol. 3, pp. 1292-1297). IEEE.

[5] K.L. Chan. (2001). Statistical analysis of final year project marks in the computer engineering undergraduate program. IEEE Trans. Educ. 44(3); 258-261.

[6] T. Clear, M. Goldweber, F. H. Young, P. M. Leidig, & K. Scott. (2001). Resources for instructors of capstone courses in computing. SIGCSE Bulletin, 33(4), 93–113.

[7] C. Domínguez Pérez, A. Jaime Elizondo, F. J. García-Izquierdo, & J. J. Olarte Larrea. (2012). Supervision typology in computer science engineering capstone projects. J. Eng. Educ. 101(4), 679–697.

[8] P. D. Ellis. (2010). The Essential Guide to Effect Sizes Statistical Power, Meta-Analysis, and the Interpretation of Research Results textbook. Cambridge University Press.

[9] V. Farrell, G. Ravalli, G. Farrell, P. Kindler, & D. Hall. (2012). Capstone project: fair, just and accountable assessment. In Proceedings of the 17th ACM annual conference on Innovation and technology in computer science education (pp. 168-173). ACM.

[10] D. Feather, J. R. Anchor, & C. J. Cowton. (2014). Supervisors' perceptions of the value of the undergraduate dissertation. Int. J. Manag. Edu. 12(1), 14-21.

[11] R. M. Felder & L. K. Silverman. (1988). Learning and teaching styles in engineering education. Eng. Edu. 78(7), 674-681.

[12] T. Gill & A. Ritzhaupt. (2013). Systematically evaluating the effectiveness of an information systems capstone course: Implications for practice. J. Inf. Technol. Edu.: Res. 12(1), 69-94.

[13] M. Goodwin & S. Mann. (2007). Multiple perspectives on a Capstone Project. In S. Mann & N. Bridgeman (eds.), Proceedings of the 20th Annual Conference of the National Advisory Committee on Computing Qualifications (pp. 73-80).

[14] H. A. James, K. A. Hawick, & C. J. James. (2005). Teaching students how to be computer scientists through student projects. In Proceedings of the 7th Australasian conference on Computing education-Volume 42 (pp. 259-267). Australian Computer Society, Inc.

[15] J. E. F. F. Jawitz, S. U. E. L. L. E. N. Shay, & R. Moore. (2002). Management and assessment of final year projects in engineering. Int. J. Eng. Educ. 18(4), 472-478.

[16] M. Joy. (2009). Undergraduate Computing Projects—an Investigation into the Student Experience. Innovation in Teaching and Learning in Information and Computer Sciences, 8(1), 60-78.

[17] K. Keogh, L. Sterling, & A. Venables. (2007). A Scalable and Portable Structure or Conducting Successful Year-long Undergraduate Software Team Projects. J. Inf. Technol. Edu. Res. 6(1), 515-540.

[18] J. Kruger & D. Dunning. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. J. Pers. Soc. Psychol. 77(6); 1121–34.

[19] Y. C. Lan & J. A. Ginige. (2008). Towards criteria based allocation of capstone projects for an enhanced learning experience. In 2008 International Conference on Computer Science and Software Engineering, vol. 5, pp. 121-124.

[20] S. P. Magleby, R. H. Todd, D. L. Pugh, & C. D. Sorensen. (2001). Selecting appropriate industrial projects for capstone design programs. Int. J. Eng. Educ. 17(4/5), 400-405.

[21] J. A. Marin, J. E. Armstrong, & J. L. Kays. (1999). Elements of an optimal capstone design experience. J. Eng. Educ. 88(1), 19-22.

[22] T. S. Wook, N. M. Ali, M. Mohd, S. Saad, J. Salim, A. Yahya, S. M. Arif, L.Q. Zakaria, A. Ismail, S. F. Mat Noor, & N. A. Mat Zin. (2012). Trends in the Final Year Project for Multimedia Undergraduate Programme: Supervisory Experience. Procedia Soc. Behav. Sci., 59(17) 399-405.

[23] J. M. Nelson, P. F. Cook, & G. Raterink. (2013). The Evolution of a Doctor of Nursing Practice Capstone Process: Programmatic Revisions to Improve the Quality of Student Projects. J. Prof. Nurs. 29(6), 370-380.

[24] P. Orsmond, S. Merry, & K. Reiling. (2004). Undergraduate project work: can directed advisor support enhance skills development? Assess. Eval. High. Educ. 9(5), 625-642.

[25] L. A. J. Stefani, V. N. Tariq, D. J. A. Heylings, & A. C. Butcher. (1997). A comparison of tutor and student conceptions of undergraduate research project work. Assess. Eval. High. Educ. 22(3), 271-288.

[26] R. H. Todd, C. D. Sorensen, & S. P. Magleby. (1993). Designing a senior capstone course to satisfy industrial customers. J. Eng. Educ. 82(2), 92-100.

[27] R. H. Todd, S. P. Magleby, C. D. Sorensen, B. R. Swan, & D. K. Anthony. (1995). A survey of capstone engineering courses in North America. J. Eng. Educ. 84(2), 165-174.

**Juan J. Olarte** received the Ph.D. degree in Computer Science from the University of La Rioja, Spain, in 2015. He is currently an associate professor at University of La Rioja. His research interests include e-learning, and innovative ways to teach engineering concepts.

**César Domínguez** received the Ph.D. degree in Mathematics from the University of La Rioja, Spain, in 2003. He is currently an associate professor at University of La Rioja. His research interests include e-learning, innovative ways to teach engineering concepts, and formal methods.

**Arturo Jaime** received Ph.D. degree in Computer Science from the University of the Basque Country, Spain, in 1999. He is currently an associate professor at University of La Rioja. His research interests include e-learning, and innovative ways to teach engineering concepts.

**Francisco J. García-Izquierdo** received a Ph.D. degree in Telecommunications Engineering from Universidad de Zaragoza, Spain in 1999. He is now an associate professor at University of La Rioja. His research interest includes technologies for web applications, modeling theories and innovative ways to teach engineering concepts.