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Assessing Team Work in Engineering Projects*

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Team work is considered a valuable teaching technique in higher education. However, the assessment of an individual's work in teams has proved to be a challenging task. Consequently, self- and peer-evaluations are becoming increasingly popular for the assessment of individuals in a team work, though it is essential to determine whether students can judge their own as well as their peer's performance effectively. Self- and peer-evaluations have been applied in different disciplines and their authenticity with regard to teacher's assessment has been evaluated in the literature but this issue has not been investigated in the field of engineering education so far. In this study, a peer- and self-assessment procedure is applied to the evaluation of a project work conducted in teams of 3 or 4 students. The participants were engineering students taking two similar courses related with database design and development. It is found that a majority of the students were unable to assess themselves as objectively as their instructor. Further, it is observed that successful students tend to under-estimate, whereas unsuccessful students tend to over-estimate, their own performance. The paper also establishes that the results of self-assessments are independent from the gender factor.

Keywords: engineering education; self-assessment; team work; performance; Z-test

1. Introduction

Team work, also referred to as 'group work' is considered as one of the most useful ways in teaching, especially in higher education. Group consciousness and the ability to create a common study environment which can lead to the team's success encourage educators to include group work activities in their teaching agenda. Team work can be chosen as a teaching strategy since it facilitates the students' understanding and motivates them towards the achievement of a common goal [1]. Elliott and Higgins [2] state that group works can facilitate both knowledge acquisition and the development of teamwork skills, both of which are essential for the professional practitioner. Group works are preferred not only for learning but also for the improvement of the social skills. In an another study [3], the majority of students indicated that working in teams contributed to their understanding of the subject, that they gained on a personal and social level and that they have learned more in the group than they would have by learning individually. However, the assessment of the individual's work as a part of a group has proved to be a challenging task, and, since it is not easy to grade each student's work, instructors tend to grant the same grade to the entire group. It has been stated that once the same mark is assigned to the individual members of the group, this grade can be irrespective of their contribution [2]. According to the studies performed, students are not satisfied with group work, because the same mark is assigned to each team member [4]. It has also been pointed out that "social loafing" and "free-riding" are other significant problems in group works [5].

Lately, higher education has been putting emphasis on incorporating self- and peer-assessment into the grading system: students assess their own learning, performance and achievements during self-assessment whereas, during peer assessment, they assess the same elements of other fellow students or group/team members in case of group/team work. Kench et al. [5] have proposed that peer assessment may act as a deterrent to social loafing and free-riding by placing value on the individual's contribution to group effort. There are various studies conducted to check the validity and reliability of self- and peer-assessment. However, there is no clear consensus whether such assessment can be as accurate as the educator's.

The motivation behind this work is to clarify the following issues: to begin with, do students and instructors evaluate the individual's contribution to team work similarly; are there any detectable trends in successful and challenged students' self-evaluation; and, finally, does a person's gender matter in evaluation trends? Although there are various similar studies [6–12] in different disciplines; to the best of our knowledge, no such study has been conducted in the field of engineering education so far. This work contributes to all those research with main emphasis on the education of engineers. Moreover, there is no widely accepted view regarding effectiveness of self-assessment yet. Results are contradictory regarding the effectiveness of self-assessment compared to teacher's assessment. Additionally, it is not proven unanimously the

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role of gender as well as student's success for effective self-assessment.

The paper has been organized in the following way: In the next section, literature review has been provided regarding the importance of self- and peer-assessment in team work and their effectiveness while grading the team members in group work. The following section presents research methods, research questions, data gathering, and analysis. Section 4 includes the discussion and the final section infers the conclusions in this area.

2. Literature review

As stated earlier, Elliott and Higgins [2] investigated whether self- and peer-assessment make a difference to student work group and concluded that self- and peer-assessment influence the individual's perceptions of the fairness of the assessment system and enhance their motivation in group work. Furthermore, the students become less dependent on their teachers, responsible and autonomous; they take on a more proactive role and develop self-confidence, while the teachers can evaluate the effects of their teaching efforts more accurately and objectively [13]. Goldfinch and Raeside [14] proposed a method in which, firstly, the group member's performance and, secondly, the contribution of the individual to the group's dynamics were measured. Willey and Freeman [15] reported the use of an online tool to facilitate confidential self- and peer-assessment and focus students' efforts on learning and practicing the skills required for teamwork. Self- and peer-assessment was found to improve students' groupwork experience, reduce the instances of free-riders and encourage students to improve their professional skill development [15].

More specifically, fairness of the self- and peer-assessment is an important subject to consider since learners do not usually assess each other objectively: for instance, there are those who tend to protect other team mates. Student perceptions of the authenticity of assessment and feedback play a positive role in student learning [16]. Shui et al. [17] have found that the interpersonal relationship between group members constitutes a major challenge in achieving fairness in peer-assessment ratings. Gopinath [6] found that gender did not contribute to the differences observed among instructors', peers', and self-evaluations. However, Lind et al. [18] examined the accuracy of self-perceptions of female and male medical students rotating on a surgical clerkship, and found that the female students significantly under-estimated their abilities in several competency domains compared with faculty assessments; whereas the male students accurately assessed, even over-estimated, their own abilities. On the contrary, Minter et al. [19] concluded in their study that, although there was a trend toward a greater degree of under-estimation of ability by female residents, significant differences were not found between the self-perceptions of female and male surgical residents. Langan et al. [7] found that females under-estimated their own performances whereas males assessed themselves with high accuracy when compared with tutor-graded marks.

Boud [20] argued that student-derived marks could not be used in grading since they would not be precise. Also Boud and Falchikov [8] reported that successful students tend to under-estimate themselves where relatively unsuccessful students over-estimate themselves. This is also supported by various studies [6, 9, 10]. On the contrary, Stefani [11] concluded that the assessment of the students can be as reliable as the teachers' one; and stated that her study can reduce the doubt regarding the over-estimation of lower achievers and the under-estimation of higher achievers. Similarly, Lindblom-ylanne et al. [12] found that the results of self-assessments were very similar to those of peer's and teacher's assessment. Langan et al. [7] found in their study conducted at multiple universities that, unlike peer grades, self-assessment was not strongly associated with tutor grades (due in part to females undervaluing their performances).

These studies have been carried out in various disciplines such as Gopinath [6] in business administration, Boud and Falchikov [8] in social sciences, Ryan et al. [9] in pharmacy education, Stefani [11] in biological sciences, Burchfield and Sappington [10] in psychology, Lindblom-ylanne et al. [12] in law, and Langan et al. [7] in the field of biological/environmental sciences. The present study has been conducted with undergraduate students of computer engineering, software engineering, information systems engineering, and industrial engineering.

Although Willey and Freeman [15] also carried out their study in three core engineering subjects, they examined the effectiveness of using self- and peer-assessment to improve learning outcomes whereas the objective of the present study is different. This study aims to find the effectiveness of students' self evaluation and whether students and instructors evaluate the individual's contribution to team work similarly.

3. Research methodology

3.1 Background

A peer- and self-assessment procedure was applied to two groups of students taking two similar courses related with Database Design and Development:

one is taught to the third-year undergraduate students of Bachelor of Engineering (Industrial Engineering), while the other accommodated the third-year undergraduates in Computer Engineering, Software Engineering, and Information Systems Engineering. Although the first course is less intensive in terms of content, most of the topics appear in both courses. Also, the two courses consist of a project work, in which students implement in actual settings the concepts they learn during the theory and laboratory hours.

The above stated project is based on team work, and individuals are allowed to choose their own team members. There are 5 mandatory steps in the project with 1 last and optional step (with bonus marks). In the first course, there were 16 project teams, whereas in the second one there were 35. In general, a project team consisted of 3 or 4 team members, and only in some exceptional cases there were 2. The project teams were required to submit a report upon the completion of each step, based on which the instructor provided feedback before the next step began as the steps were interlinked. At the end of the project, each team presented the product they had developed. Here, each person ranked their team members (including themselves) according to their contribution along with the percentage of the work each had carried out. This process of self- and peer-assessment was confidential so that team members would not be able to view other's assessments. Also, the instructor of the course monitored each team's performance along with the individual members' contributions throughout the project, and ranked the team members according to their contribution along with the percentage of the work each had completed.

The assessment was on a voluntary basis: as such the number of responses is fewer than the total number of students working on the projects. Moreover, some students provided only partial information (for example, they only evaluated the rank without the contribution or vice versa). Therefore, the number of groups incorporated into the study is 13 (first course) + 33 (second course) = 46.

3.2 Research questions

This study aims to answer the following questions:

- RQ1: Is there a difference between students' self- and peer-assessment trends in the two courses?
- RQ1a: Is there a difference between students' self- and peer-assessment trends in the two courses while ranking each group member?
- RQ1b: Is there a difference between students' self- and peer-assessment trends in the two courses while assessing the contribution of each group member in the group?
- RQ2: Is there a difference between students' self-assessment trends in the two courses?
- RQ3: What is the difference between the instructor's evaluation of the students and students' self-evaluation?
- RQ3a: What is the percentage of students whose self-assessment, in terms of their rank, is the same as their instructors?
- RQ3b: What is the percentage of students who ranked themselves higher than the instructor's assessment? In other words, what is the proportion of the students who self-promote themselves?
- RQ3c: What is the percentage of students who ranked themselves lower than the instructor's assessment? In other words, what is the proportion of those who under-estimate themselves?
- RQ4: Is there a relation between the students' gender and self-assessment?
- RQ5: How most successful students, who are ranked first in each project group by the instructor, judge themselves?
- RQ5a: What percentage of the most successful individuals perceive themselves as being most successful? In other words, what proportion of most successful students are self-confident in terms of their rank in the group?
- RQ5b: If the most successful students are confident in terms of their rank, how do they estimate their own contribution to a joint project?
- RQ6: How least successful students, who are ranked last by their instructor in each project group, judge themselves?
- RQ6a: What percentage of the least successful students perceive themselves as least successful? In other words, which proportion of the least successful students are objective in terms of their rank in the group?
- RQ6b: If the least successful students are objective in terms of their rank, how do they estimate their contribution to a joint project?

3.3 Data analysis

RQ1: To answer this question, we consider the students who submitted their responses as samples from the populations of all students participating in the projects. The value of interest is the proportion p of the responses concerning the placement of each student in the group coinciding with the placement given by the instructor. Suppose that there are 4 members in a team, and that each team member is supposed to assign rank everyone, including themselves.

Then there will be a maximum of 16 responses from a single team. If p_1 and p_2 denote the population proportions for the 'objective' responses (that is, matching rankings by the instructor) in both groups, we may state our problem as follows:

Hypotheses: H_0: $p_1 = p_2$
H_1: $p_1 \neq p_2$

The level of significance of the test $\alpha = 0.05$.

The following data related to self- and peer-assessment for two groups of students have been obtained as shown in Table 1.

Since all the necessary conditions are satisfied, to test the difference between the two proportions we use the Z- test based on the test statistic:

$$z = \frac{\bar{p}_2 - \bar{p}_1}{\sqrt{\bar{p}(1-\bar{p})(\frac{1}{n_1} + \frac{1}{n_2})}} \quad (1)$$

(see, Ovedovitz [21]). The data in Table 1 yields $z_{obs} = 1.92$. As the critical value $z_{\alpha/2} = 1.96$, we accept the null hypothesis.

The above test shows that the proportion of the 'objective' responses in self and peer assessment is independent from the group.

Apart from evaluating the rank of each student from their own point of view, the study of their perception on the individual contribution was also conducted (RQ1b). To check whether the attitudes of students in both groups are similar, the standard deviations between the students' and instructor's estimates for the individual contributions were evaluated, and the test on the equality of the standard deviations was formulated in the following way:

Hypotheses: H_0: $\sigma_1 = \sigma_2$
H_1: $\sigma_1 \neq \sigma_2$

The level of significance $\alpha = 0.02$.

The relevant results are presented in Table 2.

The F-test based on the F-distribution with $n_1 = 120, n_2 = \infty$ (for the numerator and denominator, respectively) is applied. The observed value of the test statistic is

$$F = \frac{S_1^2}{S_2^2} = 1.375 < 1.38$$

Table 1. Data concerning RQ1 (a)

Group	No. of responses, n	No. of coinciding responses, m	Proportion of coinciding responses, $\bar{p}$
1	176	65	0.369
2	370	169	0.456
Total	**546**	**234**	**0.428**

Table 2. Data concerning RQ1 (b)

Group	No. of responses, n	Sample standard deviation, s
1	148	12.947
2	370	11.038

Since the critical value $F_{\alpha/2} = 1.38$, we accept the null hypothesis.

Based on these examinations, the two groups are identical both in terms of estimating the rank and each individual's contribution to the team work.

RQ2 The following data are related to the self-assessment of the students in both groups. In this case, we are only considering the rank given by a team member to himself/herself. Therefore, if there are 4 members in a team, then there are maximum 4 responses obtained from a single team. Table 3 presents the total number of responses, the proportion of responses matching with those of the instructor's, the proportion of individuals who ranked themselves higher than the instructor's assessment (that is, self-promoting) and, finally, the proportion of those who ranked themselves lower than the instructor's assessment (that is, those who underestimate themselves).

To check whether the results of the self-evaluation are independent from the group, we use χ^2 contingency table test: that is, we will test if there is any statistically significant difference in the attitude between the students of the two groups. Formally, we state:

H_0: There is no difference between the proportions of each type of responses in the two groups;
H_1: There is a difference between the proportions of each type of responses in the two groups.

The level of significance $\alpha = 0.05$. The test statistic is:

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e} \right], \quad (2)$$

where f_o's are the observed values, f_e's are the expected values, the sum is taken over all cells (conventionally, the 'total' values are not included), and the number of degrees of freedom is 2 (see, for example, Ovedovitz [21], Ch. 9). The calculated observed value of the test statistic is $\chi^2_{obs} = 1.346$, which implies that we accept the null hypothesis, because the critical value is $\chi^2(2) = 5.991$.

Therefore, the test shows convincingly that the results of the self-evaluation in terms of ranks are independent from the group.

Table 3. Data concerning RQ2

Group	No. of matching responses	No. of self-promoting responses	No. of under-estimating responses	Total no. of responses
1	17	20	9	46
2	44	35	25	104
Total	**61**	**55**	**34**	**150**

Table 4. Data concerning RQ4

Peer Evaluation → Gender ↓	No. of students whose self-evaluation matches with the instructor's	No. of over-estimating students	No. of under-estimating students	Total
Female	24	21	14	59
Male	37	34	20	91
Total	61	55	34	151
$\bar{p}$	**0.4067**	**0.3667**	**0.2266**	

Taking into account the results of the test pertinent to RQ1 and RQ2, from here on we will not separate the responses obtained in the two groups.

RQ3 The preceding conclusion allows us to reply the questions under RQ3 using the data presented in Table 3.

RQ3a The obtained point estimate for the percentage p_1 of the students whose self-assessment coincide with the instructor's is: $\hat{p}_1 = \bar{p}_1 = \frac{61}{150} = 0.4067 = 40.67\%$.

A 95% confidence interval for the population percentage is $32.81\% < p_1 < 48.53\%$.

RQ3b Using the data from Table 3, we obtain a point estimate for the percentage p_2 of those who tend to be self-promoting as: $\hat{p}_2 = \bar{p}_2 = \frac{55}{150} = 0.3667 = 36.67\%$.

A 95% confidence interval for the population percentage of students exhibiting self-promoting inclinations is: $28.96\% < p_2 < 44.38\%$.

RQ3c Here, we estimate the percentage of the students who demonstrate a low level of self-confidence. In other words, they are those whose self-evaluation in terms of rank is lower than that of the instructor. The data in Table 3 produce the following point estimate for the percentage p_3 of such students: $\hat{p}_3 = \bar{p}_3 = \frac{34}{150} = 0.2266 = 22.66\%$.

A 95% confidence interval for the population percentage of students exhibiting low self-esteem is: $15.96\% < p_3 < 29.36\%$.

The results demonstrate that, for the majority of the students, their self-assessment is different from the instructors' one.

RQ4 As a first step, we will check whether the percentage of those whose self-evaluation is objective is the same for both genders. Among 150 responses related to self-assessment, 59 were provided by females and 91 by males. The classification of the responses with respect to gender has been presented in the Table 4.

The sample proportions of the objective responses are $\bar{\rho}_1 = \frac{24}{59} = 0.4068$ for the females and $\bar{\rho}_2 = \frac{37}{91} = 0.4066$, for the males. We state the following hypotheses:

$H_0 : \rho_1 = \rho_2$
$H_1 : \rho_1 \neq \rho_2$.

The level of significance $\alpha = 0.05$. We apply the Z-test based on the test statistic (1). The observed value of the test statistic $z_{obs} = -0.002$, which falls into the acceptance region for the null hypothesis, as $z_{\alpha/2} = 1.96$. Interestingly, the test does not reveal any significant difference in the proportions of the objective responses between the two genders.

Further, we apply the χ^2 contingency table test to find out whether the results of self-evaluation are independent from the gender of the respondents. That is, we state the following hypotheses:

H_0: the classifications of Table 4 are independent;
H_1: they are dependent.

The level of significance $\alpha = 0.05$. The calculations based on the test statistic (2) produce $\chi^2_{obs} = 0.079$ As a result, we accept the null hypothesis, because the critical value $\chi^2(2) = 5.991$.

The above tests show that the results of self-assessment are independent from the gender.

RQ5 Now, we draw our attention to the results of the self-assessment by the students who distinguished themselves as being either the 'most successful' (ranked first in their groups by the instructor) or the 'least successful' (ranked last in their groups).

RQ5a For the most successful student in each group, Table 5 presents the relevant data.

In this table, 19 students admit their top position in their group, while 23 estimate their rank as being lower. That is, the percentage of the students who under-estimate themselves is $23/42 = 54.76\%$, which is essentially higher than the corresponding value for all students (see the results on RQ3c).

RQ5b To examine the situation in more detail, we also considered how students ranking themselves as first evaluate their own personal contribution to the

Table 5. Data concerning RQ5 (a)

No. of matching responses	No. of under-estimating responses	Total No. of responses
19	23	42

project. The collected data is presented in Table 6. Among 19 students, who admit their top position in their groups, 7 under-estimates their personal contribution. It should be noticed that a difference between the students' and their instructor's evaluation not exceeding 5% has been considered as negligible.

It turns out that among those 19 students, 7 under-estimate their contribution to the project; that is, $23 + 7 = 30$ students out of 42. In other words, 71.43% of the most successful students under-estimated their performance in the group or, differently put, demonstrate a lack of self-confidence. On the other hand, the number of students who over-estimated their contribution (among those who ranked themselves as #1) is 5; that is, only $5/42 = 11.98\%$ of the most successful students can be viewed as inclined to self-promote. It is an essentially lower percentage than that for all students (we refer to the results of RQ3b).

It shows that, in general, most successful students' under-estimate their rank and contribution in their group.

RQ6 For the least successful students in each group, Table 7 provides related figures.

In contrast to the attitude of the most successful students, the least successful students tend to over-estimate their performance in their group as shown in the above table.

Out of 37 students, only 11 accept their being last in terms of rank; in other words, 11/37 = 29.73%, while 70.27% give the self-promoting response. It is worth pointing out that this value is much higher than the corresponding value for all students (see RQ3b).

It was also observed that among these 11 students, who accept being last in terms of rank, three are students from 2-student group as shown in Table 8.

What is more, the individual's evaluation of their own contribution yields the results below:

It is a noteworthy fact that among these 11 students, only 3 are objective in terms of personal contribution, while none of them under-estimated it.

This reveals that those, who are not successful, generally over-estimate their own rank and contribution in their group and also show a strong tendency towards self-promotion.

Table 6. Data concerning RQ5 (b)

No. of matching responses	No. of self-promoting responses	No. of under-estimating responses	Total No. of responses
7	5	7	19

Table 7. Data concerning RQ6 (a)

No. of matching responses	No. of self-promoting responses	Total No. of responses
11	26	37

Table 8. Data concerning RQ6 (b)

No. of matching responses	No. of self-promoting responses	No. of under-estimating responses	Total No. of responses
3	8	0	11

4. Discussion

According to our study, approximately 40% of the students' self-assessment is in line with the instructor's; 37% of the students tend to be self-promoting, whereas 23% of self-evaluations in terms of rank is lower than that of the instructor. The results demonstrate that, for the majority of the students, their self-assessment is different from the instructors'; henceforth it cannot be used as a reliable evaluation of their own or team's performance.

Also, it was observed that the results of the self-assessment are independent from the gender factor—a point supported by Gopinath [6] and later by Minter et al. [19]. However, the findings here are not similar to the recent study by Langan et al. [7]. One reason may be that female students pursuing engineering education tend to be more self-confident and, therefore, the results vary. Furthermore, the study conducted by Langan et al. [7] is related with the self-assessment of oral presentations, whereas the present study includes the self-assessment of a database project. On the other hand, oral presentations have been viewed as more 'male-orientated' [22], which may at least explain in part the male and female subjects' differences in their study [7].

Only 45% of 'most successful students' perceive themselves as most successful, whereas 55% of them are not self confident in terms of their rank in the group. If we examine the situation more closely and see how confident these students are in assessing their contribution in the project, we can conclude that 71% of the most successful students in fact under-estimated their contribution in the group project. Even among the 45% of those who correctly assessed their rank in the group (that is, similar to the instructor's), only 17% could assess their own contribution correctly. In addition, about 12% of the top-ranking students from each group over-estimated their contribution. This study reveals that the most successful students in general under-estimate their rank and contribution in their group implying that it should perhaps be regarded as

imperative for the educators to help such students in achieving further self-esteem and confidence in their own abilities. To some extent, the lack of confidence among the best achievers may be explained by the fact that instructors feel the need to concentrate more on encouraging the least successful students (as opposed to others) to catch up with the course demands. Meanwhile, better students remain rather unheeded by the instructors.
Here, one can convincingly see that more successful students, too, need additional encouragement and appraisal for their efforts.

In contrast to the attitude of the most successful students, the least successful ones tend to over-estimate their performance in their group. It was found that only 30% of the 'least successful students' were objective in terms of their rank in the group. Nonetheless, 8% (out of the objective 30%) are from 2-student project groups. 70% of the least successful students over-estimated their own rank in their group. During a closer examination of the individuals' self-assessment regarding their contribution to the group work, it was found that 92% of the least successful students over-estimated their contribution whereas none under-estimated their contribution. Only 8% among them were objective about their contribution to the group work. One may speculate the reason for this to be that these students are unable to analyze critically and objectively their contribution and efforts in team work, and that they need to be shown by their instructors that despite self-confidence having a high degree of importance for overall success, self promotion has to be based on real achievements.

The results of this study are in sync with the original study of Boud and Falchikov [8] and other studies [6, 9, 10] which stated that successful students tend to under-estimate themselves where relatively unsuccessful students over-estimate themselves. Yet, the results here are in contrast to those obtained by Lindblom-ylanne et al. [12] and also by Stefani [11] who stated that the assessment of the students can be as reliable as their instructor's.

From this research, it can be derived that students possess different understanding about their contribution to the team, some of which could be considering the amount of work, the number of hours, or the degree of creativity allocated to the task. For example, one may assume that he/she spent more time on the project compared to others in the team and, therefore, his/her contribution is the most while other may think that he/she provided the solution of the most difficult part of the project so his/her contribution is maximum. Another possibility is that learners are not aware of a systematic way of working on a given project and, although they might have spent many hours and days working on it, such efforts could not be transformed into real work in the project. With this in mind, it will perhaps be helpful for the students if the instructors provide a standard checklist for self-assessment so that they can measure their contribution more effectively against the same attributes as the rest of the team members. It will be interesting to include communication and collaboration issues in further studies as these are significant attributes in engineering projects [23, 24].

The limitation of this study is that the results are based on group projects in two similar courses (Database Design and Development) making it essential to carry out identical studies in other courses of the engineering discipline. As such, it is obviously premature to consider the present results as final; since there is a lack of similar type of studies in the field of engineering with which the authors can compare their results. Furthermore, results are not unanimous from the studies conducted in different other disciplines. Therefore, more work need to be conducted in different settings to draw sound conclusions in this respect.

5. Conclusions

As an outcome of this research, it has been concluded that a majority of the students were unable to assess themselves as objectively as their instructor. Furthermore, it has been established that successful students tend to under-estimate, whereas unsuccessful students tend to over-estimate, their own performance. Consequently, self-evaluation cannot be regarded as a sound indicator of the students' performance in a team project. The paper also demonstrates that the results of self-assessments are independent from the gender factor. All of these findings are pertinent to self-assessment of engineering students during team work of database design and development projects.

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