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A Psychological Evaluation of a Competition-based Learning Environment

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Authors' contributions

This work was carried out in collaboration between all authors. Author TW designed the car lab experiment and contributed to the analysis. Author ZL studied related work, contributed to the analysis and prepared the manuscript. Authors YD and XD participated in the car experiment. Author CC gave continuous advice on the whole study. All authors read and approved the final manuscript.

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ABSTRACT

This paper introduces a psychological analysis of the behavior of a group-based project. This approach is based on an experimental study of a car lab competition. Several cognitive and physical criteria have been self-evaluated by the student members of the competition teams, and recorded on a daily basis prior to the competition. The results reveal a series of significant patterns that outline some noteworthy relationships between the final competition outcome and some cognitive states such as expectation, investment, stress and fitness. The novelty of the approach lies in the development of an observation framework at a low level of abstraction, and that provides a complementary psychological and physical monitoring system for the full benefits of both students and teachers. Another important outcome is that clearly this kind of project learning and proactive environment favor the development of hands-on and collaboration skills.

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1. INTRODUCTION

During recent decades, project-based teaching and learning have been shown to be attractive methods that can improve engineering education significantly. They not only place students at the core of teaching and learning activities but also give them the ability to transfer their acquired scientific knowledge into practice [1]. There is indeed strong evidence for the benefits of having students actively working, collaborating and then learning in groups. Students can apply practical learning skills during a course to stimulate a project-based group process. By putting a learning process into practice, students gain additional hands-on experience thus promoting academic performance. Indeed, prior to the emphasis on engineering science, most engineering instruction took place in conventional laboratories [2]. In order to promote quality-oriented engineering education and cultivate college students' comprehensive ability to maximize their knowledge, it soon clearly appeared that engineering practice abilities, teamwork and appropriation of many engineering concepts should be developed [3] as well as novel forms of e-learning methods should be implemented with the rapid development of information technologies [4].

Several initiatives for the development of problem-oriented experiences have been developed in engineering education [5,6]. It has been recognized that engineering practice abilities, teamwork capabilities and effective appropriation of many engineering concepts should be further developed [7,8,9]. These also favor the development of creativity by stimulating motivation, developing group-project communication, critical thinking and leadership [10]. While cooperative learning denotes group work without close interaction between students, collaborative learning rather includes interaction, collaboration, and utilization of the group's competences [11,12]. Collaboration generates a favorable organization where each group member contributes what he is able and learn from contributions of those more expert than him [13]. Several experimental studies have been conducted to improve undergraduate engineering student skills thanks to collaborative approaches [14,15]. Other evidences show that student performance increases when appropriate motivation strategies are implemented [16]. Positive group experiences have been shown to contribute to student learning [17]. When students are working in a group project they are more motivated to achieve their tasks than they would be when working individually. It has been already observed in previous studies that competition-based group projects largely stimulate and improve students' performance [18]. However, the reasons behind why some group work turns out more successfully than others are still not completely solved. For instance, cognitive psychology studies provide clinical evidence that stress and low motivation can interfere negatively with learning [19].

This experimental research introduces an evaluation of the psychological factors that influence the outcomes of a group-based engineering project. It is based on a national competition project. In our previous work, the technological settings of the car lab competition as performed by several students' teams at the Shanghai Maritime University have been introduced [2]. In the present paper, we further study the different psychological factors that influence the car lab competition outcomes. While performing and preparing a car-automated competition, students' behavioral and psychological states have been self-recorded by the members of the different teams involved. This survey has been performed during the whole week of a competitive group project pre-competition. The objective is to study to which degree the psychology of the team and physical states during this pre-competition have an impact on the overall performance and learning outcomes on the students and competition. The goal is to deepen the understanding of how the psychology of the teams influences their overall performance during the whole process of the competition preparation and execution.

The rest of the paper is organized as follows. Section 2 presents additional background on the competition principles while Section 3 develops the different categories of teams involved. Section 4 provides a brief report on the competition outcome while section 5 introduces the main results of the psychological and physical state evaluation. Finally, section 6 discusses the findings while Section 7 draws the conclusions.

2. COMPETITION PRINCIPLES

The National Intelligent Car Competition was originated in South Korea in 2000. The teams participating in the contest were requested to design and produce an intelligent car which can analyze the road automatically and travel on a predefined track, by using incoming geolocation data get from different senses and a self-adaptive program embedded in the Micro-programmed Control Unit (MCU) of the car. The final score of a given team all depends on the time which the vehicle uses to finish the track without getting out of the track.

The Intelligent Car Competition is now held every year in China as a national competition and involves several Chinese universities. The competition committee publishes the competition subjects and rules for the following year in November. In July, the division contest is held in different universities in order to select the best teams in every division. At last, in August, the final competition begins.

Every year universities select a few students to attend the Regional Intelligent Car Competition. This means that students have almost one year to prepare the competition. The selected students need to master basic knowledge of voltage regulator circuit and MCU. Members of the teams should have a proper division of labor. For instance, an intelligent car has three essential parts, the circuit, machinery and control product unit. Therefore, every student is responsible for one of those parts.

In November, when the new rules of the competition are published, the teams choose their group from three different groups. All the teams are asked to participate in the competition organized in order to show the outcomes for nearly half a year. Finally, every school chooses six teams to attend the Regional Intelligent Car Competition. These six teams selected for the competition begin to prepare themselves.

Every year, propositions of both the regional and national competitions are made by the competition secretariat technical team. This means that the competition rules and categories change on a yearly basis. An important component of the competition is that most criteria are objectives and evaluated by an automatic electronic evaluation system. The main tasks covered by the competition involve the mechanical design and assembling of the cars, development and debugging of the car communication and control systems, implementation and evaluation of car sensors, integrated information processing and algorithm design. The whole process involves several domains knowledge such as algorithm development and control, sensor technology, automobile machinery, computer technology, electric control design and energy resources.

An important step of our project lies in the selection of the students and set up of the different teams. Several requirements have been considered to achieve this preliminary objective. First, collaboration is a crucial principle, so teams of three to four students have been carefully selected on a volunteer basis and using a thorough selection process. Every car has three complementary parts that should be designed appropriately and in close interaction. This means that volunteer students are selected from several colleges, this being particularly the case at the Shanghai Maritime University where students were selected from the Logistics Engineering College but also from the Information Engineering College. As the project runs for about one year, selected students should show motivation and willingness to work together along the whole period. A pedagogical objective of this competition is to combine the knowledge that students learn in class and cultivating their hands-on ability. A teacher is in charge of the management of the different teams but giving them full autonomy to organize themselves. This teacher provides specialized technical support when required and appropriate funding for material and logistics support.

With the explicit objective of competition performance and the implicit ones of acquiring technical knowledge and group-collaboration skills, the students are given several tasks such as adjusting the different car parts, designing the circuit diagrams and debugging the different programs involved. In other words, students in a team should organize themselves, setting up a series of goals according to their own expectations. Students should have a reasonable amount of positive pressure to stimulate and guide them when preparing for the competition. Last but not least, students should maintain high motivation during the pre-competition process and have a reasonable amount of pressure and stress when preparing for the final competition.

3. COMPETITION TEAM CATEGORIES

This section introduces the three competition categories predefined by the competition rules.

According to the regulations of the competition, both electromagnetic and photoelectric cars should use a four-wheel model, while for the camera group, cars only use two wheels. For the electromagnetic and photoelectric groups, cars are driven by rear wheels and direction is controlled by front wheels. For the camera balance group, cars are required to use two wheels to keep balance, control direction and speed. The respective specific characteristics of each group are respectively introduced in the following sub-sections.

3.1 Electromagnetic Car

This group is the only one that doesn't use sensitive material (Fig. 1). A wire with 20HZ and 100mA current is laid in the middle of the track. The team members of this group should first access the signal from the wire using a self-designed circuit. The signal is amplified in order to be analyzed by the MCU. Then a MCU AD converter maps the analogue signal into a digital one. Incoming data are analyzed using specialized software (such as MATLAB), the signal is processed to locate the wire in the track and to allow the intelligent car to follow that track.

3.2 Camera Car

This team uses a car equipped with a mini camera (Fig. 2). Regarding processing time, this setup is the fastest one because of the most comprehensive track information the camera gets. The team is asked to design the circuit that transfers the analog image into a digital image that can be then processed by the MCU. Then the MCU processes and rectifies the image longitudinal distortion and transverse proportion distortion using a trapezoidal algorithm [20]. At last the program should extract the left and right lines so as to calculate the middle line of the track.

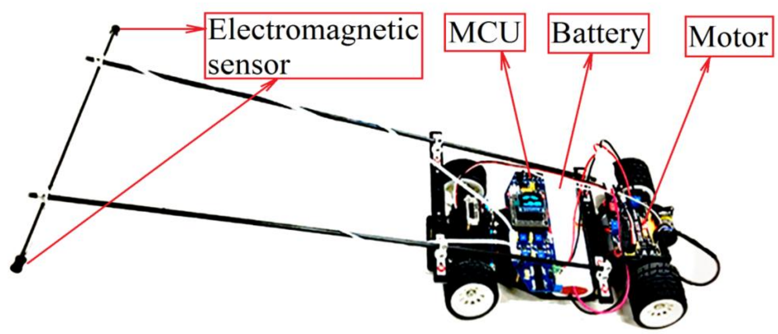

Fig. 1. Electromagnetic car

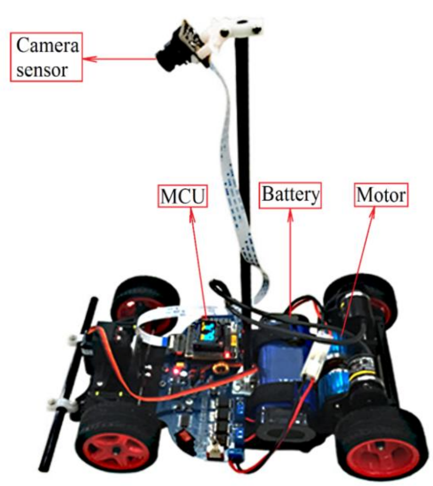

Fig. 2. Camera car

3.3 Photo-electric Car

The basic working principle of a photo-electric car is that two or three linear CDDs (Charge-coupled Device) [21] are used to get some incoming data on the tracks (Fig. 3). The principle is similar to an analogy car but here two or three linear CDDs are applied before the MCU can make a difference between the right and the left in order to locate the middle line of the track. Another important property of the photo-electric car is that it only has two wheels so in order to provide sufficient stability the car needs to keep a right balance using the two wheels while following the track. This is ensured using gyroscope and accelerometer data. Using the key principles of angular momentum, the gyroscope gives the angular acceleration, while the accelerometer measures linear acceleration based on vibration. Such incoming data is used to keep the car balanced.

4. COMPETITION OUTCOME

The Intelligent Car Competition in Eastern China was held from 24th July to 27th July 2015. 298 teams from 65 universities participated for an amount of more than one thousand students and teachers in charge (Fig. 4). The teams are organized and hereafter named as follows:

- Team Camera 1 and team Camera 2 for camera cars;
- Team CCD 1 and team CCD 2 for photo-electric cars;
- Team ELE 1 and team ELE 2 for electromagnetic cars.

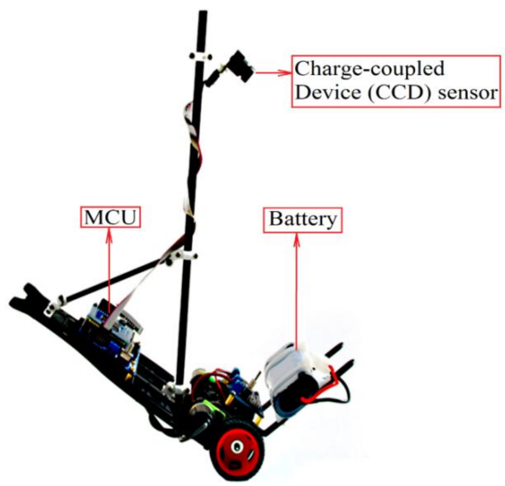

Fig. 3. Photo-electric car

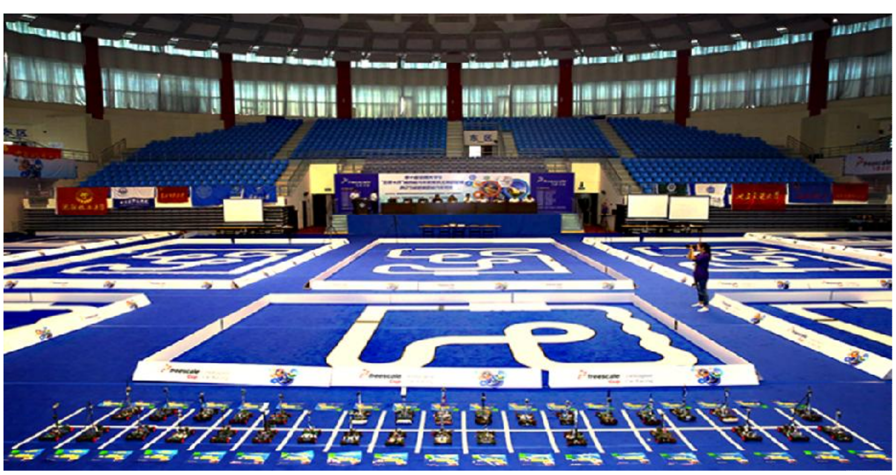

Fig. 4. Car competition setup

Before the competition, the students were allowed to debug their cars if necessary in order to fit it to the race environment. For example, one of the camera groups adjusted the threshold of the camera light sensor while a photo-electric group made every effort to set up the best car balance and an electromagnetic car group has to adjust the incoming signal. Finally, after a thorough debugging process the circuit race was released the day of the competition as it was kept secret until the last moment. For each team not only it was essential to perform as quickly as possible but also without getting out of the track in order to avoid premature elimination. Table 1 shows the final outcomes of these teams.

Table 1. Competition final results

	Ranking	Prize
Team Camera 1	NO.19	Second prize
Team Camera 2	/	Consolation prize
Team CCD 1	NO.18	Second prize
Team CCD 2	/	Consolation prize
Team ELE 1	NO.15	Second prize
Team ELE 2	NO.24	Second prize

5. PSYCHOLOGICAL PHYSICAL STATES EVALUATION

With the purpose of reflecting the actual influence of the teams' psychology and physical state of the students' respective performance, a questionnaire has been set up and fill-in on a daily basis by the different team members during the whole week of the pre-competition process. At first, the team groups and respondents have been selected and organized. Next a questionnaire has been set up to evaluate the students' behavior day-by-day the week before the completion (Fig. 5). The variables selected provide a general approximation of the evolution of the students' and teams' psychological and physical conditions. To give an acceptable tracking method, we selected four complementary variables: expectations and investments, stress and fitness. While expectations provide a view of the initial objectives of the competitors, and investment the degree of their respective implication, stress denotes the pressure exhibited by a given student, and fitness the student condition.

5.1 Questionnaire Principles

The objective of the questionnaire is to reveal students' expectations, investments and stresses, and fitness during the whole pre-competition week. While those parameters encompass different psychological and physical states, they are indeed interdependent. At first, students and group expectations give the levels of motivations of the different teams. These expectations are recorded individually in each group, but their analysis can be performed at the individual and group levels to reveal different group patterns. In particular, the level of students' investment is largely dependent on their expectations [22] (i.e., the higher their expectations the higher their investment is likely to be) and it is a key feature of potential success. On the other hand more reasonable goals are more likely to produce a minimum level of student stress. Last but not least student's fitness, or at least the student perception of his own fitness, due to the cumulated influence of investment and stress, is another important parameter to take into account. When the start of the competition is closing in, students are likely to increase their level of investment, then excitation and pressure raise and consequently their fitness is likely to be impacted.

The objective of the questionnaire is not only to evaluate each student's perception of his/her own status regarding the car competition; but also the one of the other team members. Indeed, and as teamwork is privileged, every team member should have a reasonable knowledge and perception of his/her colleagues' status in the team. This, in fact, should not only demonstrate some cognitive perception capabilities, but also good communication between the team members. Team collaboration and communication should not only combine the wisdom and status of each individual but also favor an in-depth understanding of the other members. The questionnaire has been filled in by every student every day the week before the competition.

Fig. 5. Learning process observation principles

All questions are evaluated qualitatively and gradually as the objective is not – and cannot be – to give a precise evaluation of the different parameters identified, but rather to deliver a reasonable approximation that will support further analysis. For example, and the same principle is applied to all questions, question 1 evaluates the level of stress that gradually decreases from response A to E (i.e., valued from 5 to 1). The questionnaire analysis should analyze several complementary patterns such as the value and evolution versus stability of each of these parameters for every team member, as well as within a given team to cross-comparison between different teams. All patterns have been analyzed during the competition process at different times in order to provide a clear picture of the evolution. Finally, a study of the cross-relation between these overall patterns and team's performance at the final competition has been performed.

5.2 Psychology and Physical State Evaluation

5.2.1 Students' expectations

Amongst the different variables identified, expectations are the first one to emerge as students have some reasonable intentions when been volunteers and then selected as members of a team. However, as illustrated in Fig. 6, such expectations as summarized within each tea, they greatly vary along the week before the competition at the exception of team Camera 2 that maintains a "winner" objective along the week. A first trend that emerges is a daily variance of the student expectations when the day of the competition comes closer. At the exception of team Camera 2 whose expectations are very high and stable, others vary to reach a relatively high level with the exception of team CCD 2 that has a significant drop in expectations. On the other hand, team Camera 1 has a continuous decrease of its own expectations although its performance has been relatively good (2nd prize at the final match). Overall, the other teams get more confidence on their expectations the day before the competition, this reflecting relatively high confidence.

5.2.2 Students' investment and other students' investment

The investment criteria are evaluated as well as the evaluation of the own investment of each team member (Fig. 7), and the investment of the other members of the team (Fig. 8). As for the expectation and investment graphs, both show a relative variability. In particular, it appears that team Camera 1 has a higher investment value at the start but keeps decreasing along the week. On the other hand, team Camera 2 that already has high expectations, also has a progressive increase in investment this denoting a valuable ad equation between expectations and investments. Team CCD 1 has an average investment value that progressively decreases. This might denote either demotivation or success in the preparation of the cars the later being, in fact, the case for that team. On the other hand, team CDD 2 has the lowest investment value this both denoting a lack of investment and probably some crippling preparation problems. Overall these patterns are variable along the teams and pre-competition week.

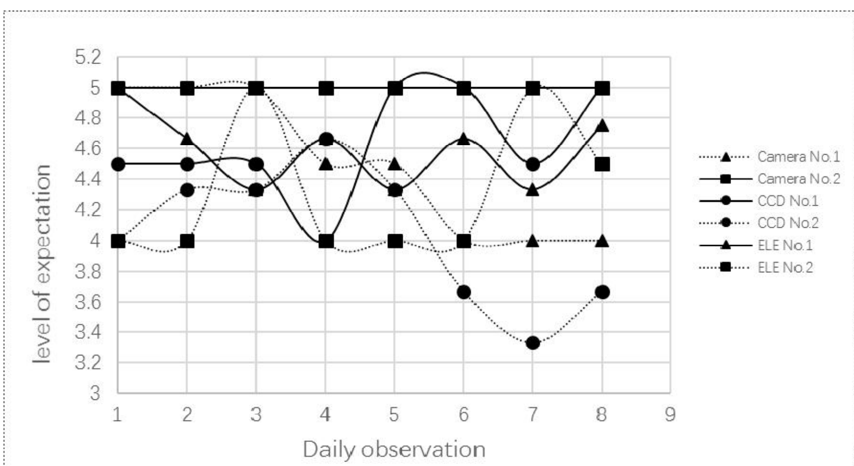

Fig. 6. Students' expectations

One can also observe a very positive trend regarding the student perception of the other members of the team investment when the competition is closing (Fig. 7). It appears that on average students have a better perception of the other members of the team investment than their own investment. Overall it also appears that for example the investment of team Camera 1 matches relatively well with the expectation this being even the case for team CCD 1 and partly for team ELE 1 and team Camera 1. The students seem to have a more positive evaluation of the other members' investment than their own. A specific trend is the one revealed by team Camera 2 where the members of the team have a bad evaluation of the other team members' investment this potentially revealing a discrepancy within the group that might be caused by a non-optimal distribution of the tasks, this being bad news for the team's performance.

5.2.3 Students' stress and other students' stress

As for the stress, the other students' stress is exhibited as self-perceived by the students and for all of the other members of the team (Figs. 9 and 10, respectively). A noteworthy trend appears: regarding the level self-evaluated or evaluated for the other members of the team, the level of stress is generally starting at a high level, and slightly increasing then decreasing smoothly in the middle of the week for reaching a maximum the day before the competition. Another general pattern that appears is that overall students feel themselves much more stressed than the other members of the group,

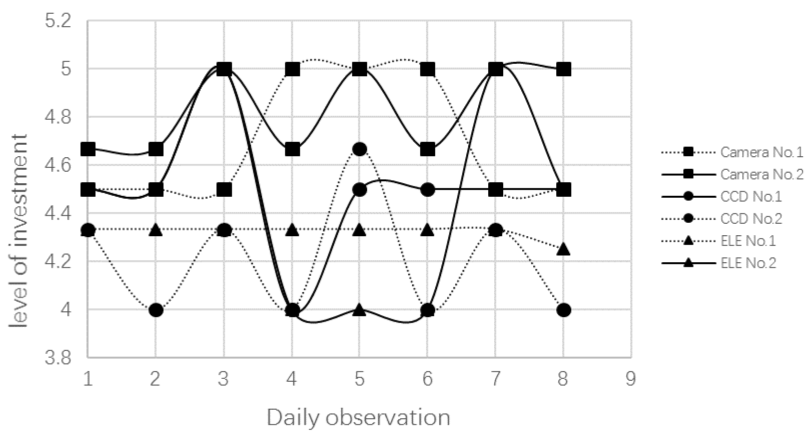

Fig. 7. Students' investment

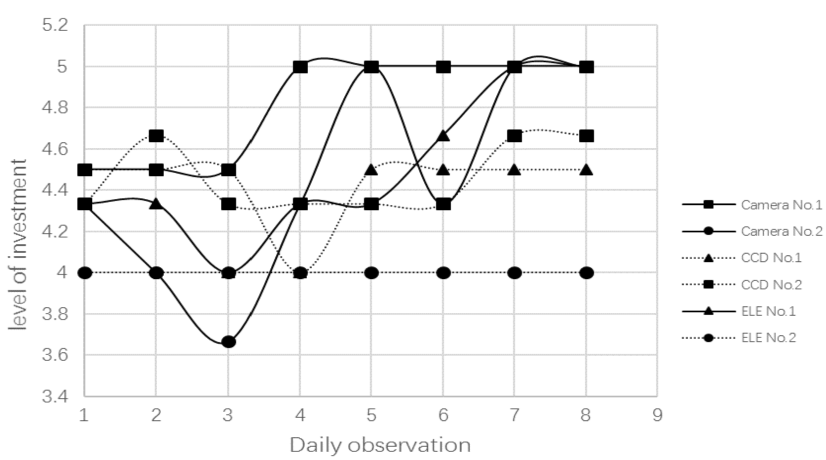

Fig. 8. Other students' investment

this being a strong pattern, this probably denoting the fact that a student under stress has lost his/her ability to evaluate the psychological state of his environment and notably the ones of his team mates (or possibly sur-evaluating his/her own stress). When compared to the previous figures it appears that team Camera 2 is under pressure, this being probably due to high expectations and investments (the final outputs shows that this team didn't perform well the day of the pre-qualification). In particular, it also appears that team Camera 1 and team CCD 1 have an average stress value when compared to the other groups. Team Camera 2 is under high and increasing stress this denoting too much pressure and unfortunately, this being also reflected by the final poor result of this team, this being even partly the case for team CCD 2.

5.2.4 Student's fitness

Amongst the different variables identified, fitness directly shows the physical status of the students as these have been directly affected by the pre-competitive process. As illustrated in Fig. 11 (where 5 means very tired while 2 means not tired at all), there is an overall increase of the fitness of each team, although all fitness start at different degrees of magnitude. Overall a significant trend is that the level of tiredness increases along the pre-competition week this being a reasonably expected trend. Team Camera 2 and team CCD 1 have very high levels of stress at the start of the competition this surely being bad news for the competition output. On the other hand, team ELE 1 and team ELE 2 have lower stress values this favoring reasonable performance.

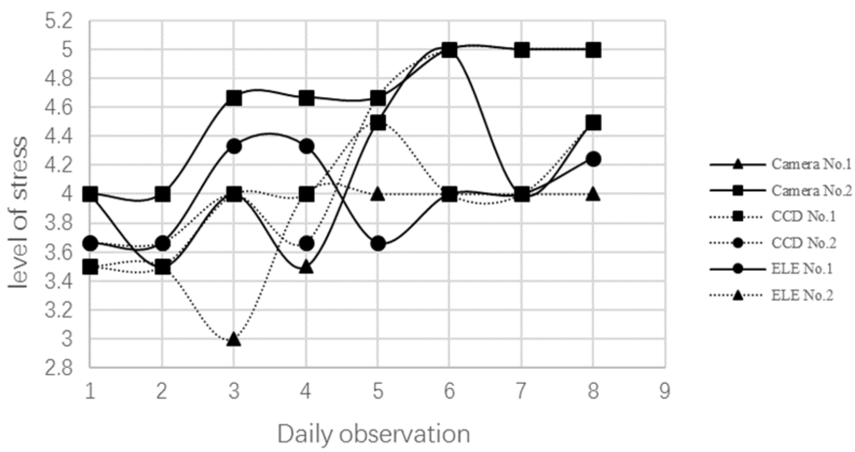

Fig. 9. Students' stress

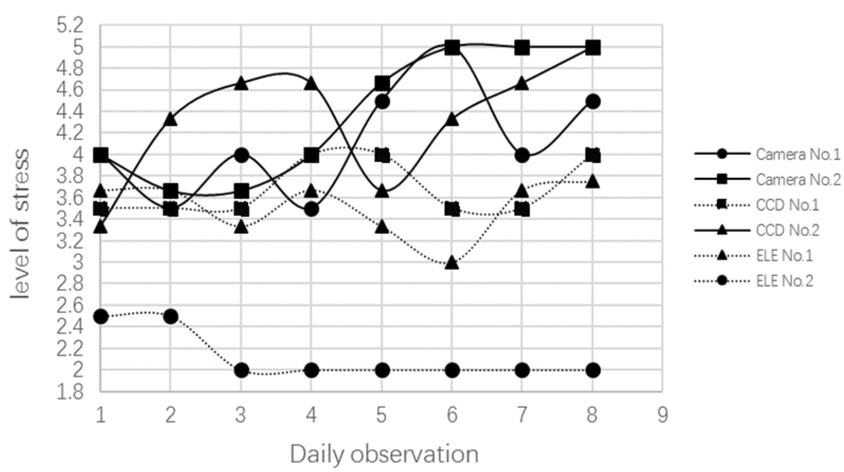

Fig. 10. Other students' stress

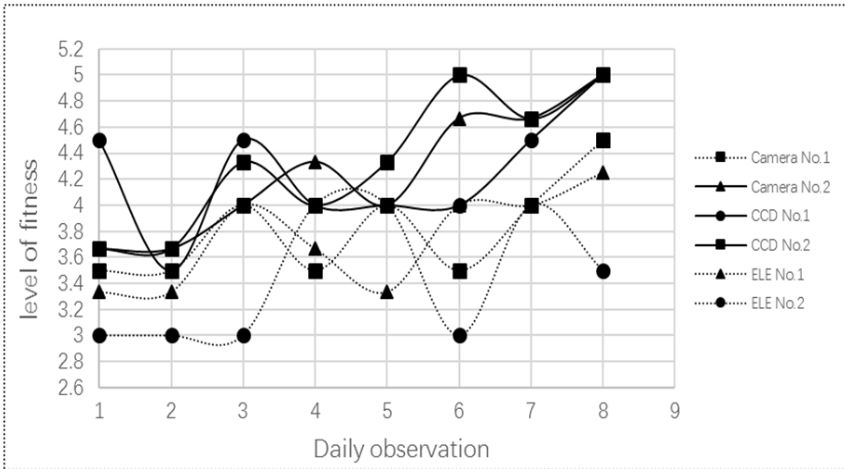

Fig. 11. Students' fitness

It appears that the two teams that have the relative best fitness the day before the start of the competition are teams ELE 1 and ELE 2, those two groups being the ones that achieve relatively good results. On the other hand, the two groups with the worst fitness are the ones that got no scores (team Camera 2 and team CCD 2). This shows the correlation between the level of fitness and competition results. Another noteworthy trend is the overall decrease at the middle stage of the pre-competition, this being slightly correlated to the level of stress outlined in the previous sub-section.

6. RESULTS AND DISCUSSION

Overall this study shows some valuable tends when comparing the competition results to the group psychological and physical evaluations (cf. Figs. 6 to 11).

When expectations converge with the level of investment and the fitness is at a low level, the final outcome is likely to be positive (e.g., team Camera 1 whose final rank is 19th). When expectations are at a high level as well as the competitor's own investment and the other members of the team investment, the final performance is likely to be positive (e.g., team CCD 1 whose final rank is 18th). When high expectations match low stress and fitness, the final outcome is likely to be positive (e.g., team ELE 1 with a rank of 15th and team ELE 2 with a rank of 24th). When both stress and fitness are at a high level, the final outcome is likely to be negative (e.g., team Camera 2 with no score). When low expectations converge with investment, the final performance is likely to be negative (e.g., team CCD 2 with no score).

Additional aggregated figures show the averages of expectation, investment, stress and fitness for the different teams (Table 2). Both expectation and investment have positive impacts on the team's outcomes. For example, team CCD 2 with the lowest expectations didn't perform well in the competition, while team ELE 1 had much higher expectations than team ELE 2 and then team ELE 1 performed much better than team ELE 2 (Team ELE 1 ranked 15th while team ELE 2 ranked 24th). Team CCD 2 with low investments got no score. Both stress and fitness have negative correlations with the team's performance in the competition. Finally, Team Camera 2 and team CCD 2 that had high stress and fitness didn't perform well at the competition. Overall the questionnaire analysis shows some emerging patterns that outline a series of influences on the students' expectations on their respective levels of investment, stress and fitness. It also appears that high expectations and investment often generate high stress this having a negative impact on the team fitness and performance.

A detailed analysis and a tentative generalization are difficult to reach but such psychological evaluation approach can be also considered as a daily tracking and monitoring system that can be useful for the teachers in charge. This was the case during the pre-competition week as the questionnaire was recorded on a daily basis and then regularly given to the teachers in charge. This was another important interest of the

Table 2. The averages of expectation, investment, stress and fitness for the different teams

	Team Camera 1	Team Camera 2	Team CCD 1	Team CCD 2	Team ELE 1	Team ELE 2
Expectation	4.50	5.00	4.63	4.17	4.64	4.19
Own investment	4.69	4.83	4.56	4.21	4.32	4.43
Others' investment	4.81	4.46	4.50	4.46	4.50	4.00
Own stress	4.12	4.62	4.06	4.33	3.95	3.75
Others' stress	3.88	4.34	3.69	4.33	3.64	2.13
Fitness	3.81	4.25	4.25	4.33	3.74	3.44

questionnaire analysis as teachers were promoting discussions with the students when some alarming patterns emerge.

Overall, it clearly appears that from post-competition discussions with the students that their hands-on abilities have been greatly improved during the whole process. More noteworthy, the psychological and physical evaluations give them a sort of monitoring system that acts not only as a performance diagnosis tool, but also a way of self-evaluating their respective levels of implication and physical state. The framework shows the importance of their external factors on the students and groups performance. For every student the framework provides a self-learning mechanism to learn more about his/her own abilities in a group-project and competition context; For a teacher, it provides a valuable solution to observe how students perform in such conditions. Most if not all of the students reacted positively over the process, they enjoyed the principles of the approach as well as the objectives pursued.

A promising direction still to explore lies in the fact that the whole observation system might act as a predictive system to evaluate the possible students' performance and then the probability of success of a given team. By extension and by using some prior simulations before the competition, this might lead to apply some correction mechanisms at the student level or to reorganize the different teams accordingly.

7. CONCLUSION

The research presented in this paper introduces an experimental research that conducted an evaluation of the psychological and physical state factors that influence the outcomes of a group-based engineering project. The objective is to study to which degree the psychology of the team behavior psychology and physical state during this pre-competition had an impact on the overall performance of the teams and the students' learning outcomes. The goal is to deepen the understanding of how the students' psychology and physical states influence the team's overall performance during the whole process of the competition preparation and execution.

A Chinese proverb tells us that going beyond the limit is as bad as falling short. It clearly appears from that study that expectations and investments on the one hand, and generated stress and fitness on the other hand clearly have an important impact on the teams' physical states and on the final competition outcome, Moreover, both expectations and the degrees of students' investment have positive impacts on the team's outcomes, while both stress and fitness have negative impacts on the competition outcome. This experimental study also shows how useful group-project developed in a competing and under pressure environment can be useful to student's knowledge acquisition processes as far as a good balance is maintained in between the degree of investment and its likely impact on the students' fitness. This confirms previous findings on group-project behaviors [18] but refines earlier studies by providing an observation of a series of psychological and physical variables at a lower level of granularity that favors several interpretations as well as a self-learning mechanism for both the students and the teacher. Overall, such group-based and competition environment favor development of collaboration skills that are difficult to obtain in conventional teaching contexts. Such environment has also proven to be a worthwhile experience for the teachers involved as novel mechanisms of communications with the students have been developed, and where teachers rather act as proactive observers instead of being leading the course.

As the competition is held every year, we not only plan to apply again the whole framework in the near future but also by improving the data processing level by developing a computerized monitoring interface. Another direction to explore is indeed the integration of additional psychological and physical variables in the whole process.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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