# Graduate student program of Electrical Engineering based on Industry-University Cooperation

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***Abstract*—This Innovative Practice Full Paper presents a novel educational approach to improve the quality of graduate engineering education by emphasizing real world project based learning, the state-of-the-art and state-of-the-practice technological developments, and a need for globalization. Aiming to address the challenges of educating engineers for the 21st Century, authors developed a double degree graduate program based on industry-university cooperation. This program includes a multifaceted-industry-university cooperation system, assuring the central role for industry as the crucial component in education of graduate level engineering students. The applied strategies and adopted methods are presented and discussed. After two cohorts of graduate students have successfully completed the program, the outcomes indicate that implemented educational approach has attained desired results. According to the survey results, students benefited significantly from the program and are in high demand by industry. The experience of this industry-university cooperation program can be valuable to other engineering schools and programs.**

***Keywords—Industry-university cooperation, Master program, Electrical engineering, Job market***

## I. INTRODUCTION

The aim of academic engineering programs is to educate engineers in a specific technical field. In the United States, it is understood that the holder of the engineering Master degree has completed a technically focused curriculum which is highly relevant to a standard engineering practice [1]. This goal determines the importance of a practical training during the engineering education process. As one of the most authoritative engineering accreditation organizations in the world, the Accreditation Board for Engineering and Technology (ABET) has provided standardized criteria for accrediting engineering programs. The criteria places great emphasis on abilities to apply the knowledge in practice, to solve engineering problems and to work together with others in a group [2]. However, it has been debated if these abilities could be obtained through traditional classroom-based educational approach alone[3]. Practical exercise has been considered necessary, providing students chances to practice their engineering skills. Consequently, the participation of industry in engineering education has become a cornerstone in developing and maintaining relevant preparation for real-world jobs. During the last decade, many countries in Europe have paid a lot of attention to creation and implementation of the support system which is targeted toward facilitation of industry-university cooperation [4]. Top Industrial Managers for Europe (T.I.M.E.) is the pioneer in organizing top engineering universities across Europe, Asia, and South America, whose goal is to cultivate the excellence in engineering education through close cooperation with industry and by providing good cross-cultural understanding [5]. Along with the recognition of the importance of globalization, the organization also recognizes the fact that cooperation between different countries and cultures is essential component of graduate education and successful preparation for jobs in the global economy. Global sophistication and cultural awareness have become a critical requirement for an effective engineer in the 21st century [6]. It has been widely acknowledged that traditional approach to engineering education should be transformed into new paradigm in order to address new challenges [7].

In order to address the emerging globalization requirements, an innovative electrical engineering program, based on industry-university cooperation, is proposed and implemented between Beihang University (BUAA), Beijing, China and Politecnico di Milano (Polimi), Milano, Italy. This program has developed a multilevel industry-university cooperation (MIUC) model where industry plays the most important role while taking advantage of the existing and well established cooperation between the two universities and associated cross-cultural resources. The ultimate goal of this educational model is to prepare engineering students to be effective professionals in the global economy.

The paper is structured as follows. Section II introduces this collaborative program and discusses the proposed educational model in detail. Section III presents the results of this program after two cycles. Finally, the conclusions are presented in Section IV.

## II. MULTILEVEL INDUSTRY-UNIVERSITY COOPERATION SYSTEM

In order to effectively integrate resource of the two universities and develop relevant and high quality graduate program, an innovative industry-university system is carefully designed. This system has different expectations from each of the educational system components and implements appropriate approach at every level of engineering education as indicated in Figure 1. In this system industry serves the application role whereas university serves the educational role, where professor is the linchpin between student and industry.

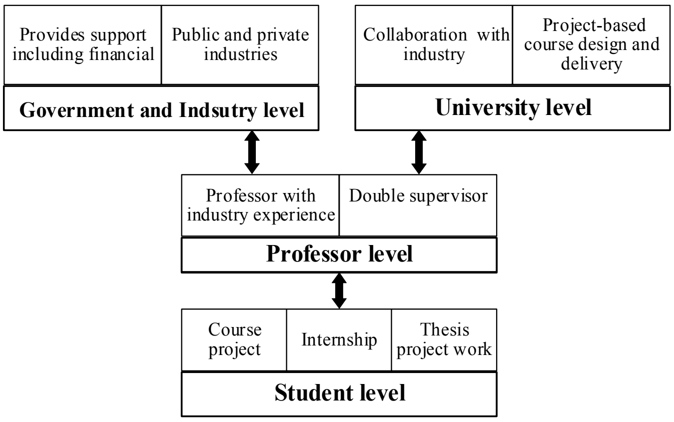


Figure 1 Multilevel Industry-university Cooperation System

After careful analysis of the industrial requirements, the MIUC system is designed as a three years program (180 ECTS credits) for students in electrical engineering. In the first academic year, students attend the courses and activities in Polimi, which awards them 68 credits. During this year, Polimi provides at least 5 advisors from industry to teach courses or to deliver laboratory experiences. The courses are designed to have practical component where all of the projects come from industry. In the second academic year, the students continue their studies at BUAA where they receive 73 credits. More than half of the course instructors are supervising at least one industrial project. Students are involved in those industrial projects throughout the entire school year. In the last academic year, students go to either European or Chinese industrial partner for more than 5 months complete two projects theses to obtain the remaining 39 credits. After completion of the three years program, students receive double Master Degrees from BUAA and Polimi.

### *A. Government and Industry level*

The industry-university cooperation has been generally recognized as essential element required for successful and relevant engineering education. In China, Ministry of Education has carried out Excellent Engineers Instructing and Training Program (EEITP) since 2010. The program aims to improve engineering education where many graduate level engineers lack practical skills, which ultimately impacts their employability [8]. In *Certain Opinions of the Ministry of Education on Implementing EEITP* in 2011, it is required to build a cooperation between universities and industry, where they jointly formulate training objectives, build curriculum, implement training process, and evaluate program quality. The undergraduate and graduate students in this program must spend approximately one year learning state-of-the-practice technology and culture in industry [9]. In Europe, European University Association (EUA), European Industrial Research Management Association (EIRMA), European Association of Research and Technology Organizations (EARTO), and European Association of Knowledge Transfer Offices (EAKTO) have jointly issued *A Guide to Better Practices for Collaborative Research between Science and Industry.* Inside this handbook, a program introduced to promote strategic collaboration between industry and universities [10]. T.I.M.E has also built a network of leading Engineering Schools and Technical Universities since its foundation in 1989. Started as an association in Europe, T.I.M.E is now making global efforts to promote collaboration between universities, industry, and professional organizations.

Under such backdrop, this double degree program, based on industry-university cooperation, has received significant support from governmental and non-governmental institutions both in China and Europe. In addition, government supported research institutes collaborate with universities and supervise engineering projects. Detailed realization of these two types of support are discussed in the following text.

*1) Bridging the gap:* From the government's point of view, it's beneficial-to combine the academic resource of universities with technical capabilities of industry. Consequently, providing financial support and guidance, governments can help build cooperative relationship between the two.

Governments can also help bridge the cultural gaps between different cultures. There are number of cooperation platforms and programs between countries, which have been created and successfully operated by governments and/or governmental organizations. They have accumulated rich experience in dealing with issues which can occur in the multicultural cooperation. These platforms and programs have made great contribution to the successful implementation of this double degree program. They provide useful solutions for easing conflict and promoting communication between students from different cultural background. For example, some "welcome week" activities are specially designed borrowing from these previous programs for double degree students, in order to help students fit in the environment quickly. Courses about Chinese/European history and culture are also provided for students to help them deeply understand the different culture.

*2) Public utilities:* When dealing with the public service affairs, the local governments are responsible for dealing with practical problems such as water and supply system and electrical grid. Some interesting engineering projects can be formulated from problems associated with these public utility systems. These projects are provided to the students as real-world examples on which to practice their engineering skills. For example, in the course on *power electronics,* the local electricity companies provide information about the city electricity distribution equipment to students. Guided tours to the local power distribution stations are also organized, helping students understand the electrical equipment and related technology. Furthermore, the students are required to complete a group project specified by the electrical power company. During the project, the students develop and analyze a simplified version of the local power distribution switching circuits, with the help of two experienced engineers from the power company. The project results are presented to the power company, with the goal to assist the company in improving the service. In addition, addressing the actual problem of a city is an effective way to cultivate student's sense of social responsibility.

*B. University level*

The two universities in this program have established long-term and strong cooperative relationships with a large number of industries, which contribute great value to the engineering education by participating in curriculum design and development, and by providing course projects and internship opportunities to students.

The universities regularly and actively engage industry in curriculum design and development, through surveys and face-to-face meetings with industry experts. Prior to the start of every semester, universities conduct industry surveys about which abilities are needed, and critically important for effectively working in industry. Based on the results, universities decide which courses should remain, what material is obsolete and can be removed, and what new material needs to be added to the program. In addition, the faculty, in collaboration with industry experts, decide what teaching objectives should be established in order to achieve desired learning outcomes and what types of teaching methods should be implemented.

The approach allows integration of more effective project content in the courses. For example, an innovative project-based course *Power Systems* is successfully implemented in this program. For an electrical engineer, the ability to analyze power system is one of the most fundamental and critical requirements. However, the complexity of the actual power system makes it almost impossible to teach the required material just by lectures within the traditional classroom.

Therefore, this course is divided into two parts and is taught both at Polimi and BUAA, as shown in Figure 2. Meanwhile, two projects relating to the course content are offered by two companies, providing students opportunity to apply theoretical knowledge in the real application.

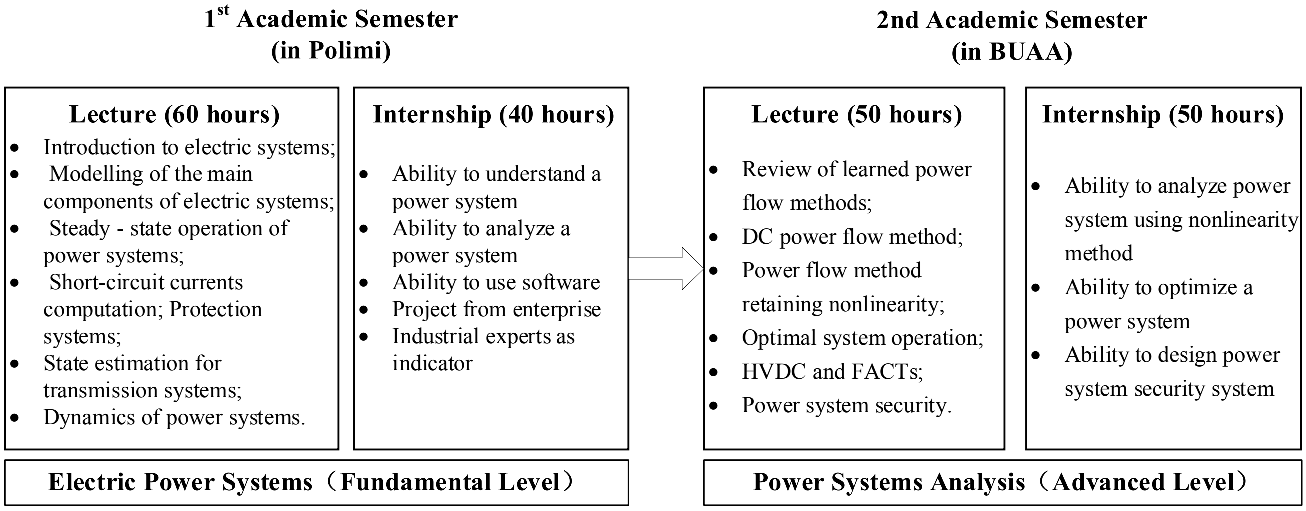


Figure 2. The course structure of *Power System*

Compared with typical projects conducted in a traditional course, these projects are based on the actual problems and recently conducted projects by the two companies. This approach guarantees that the projects represent the real world need. Besides, there is at least one expert from the company serving as an advisor for each project, and whose duty includes introducing the project to students, providing necessary help and evaluating student performance. Finally, the student performance for this course is assessed by both university faculty and industry experts.

In order to ensure the effect of project execution, students need to report their understanding of the project and determine the implementation route to industry supervisor in the first two weeks. Industry supervisor organize the team meeting and check the project time to time. Double supervisors discuss about the project situation and students work in the beginning, mid-term and final. Double supervisors score the students work each stage. The final score is given in comprehensive way considering student's final presentation of project and scoring at various stages.

Upon graduation, students of this program have opportunity to enter big companies in both countries. There are more than 300 companies in various engineering areas, including Huawei and Tencent in China, and ABB and Siemens in Europe. Those companies provide more than six thousands internship jobs for the students every year. Distribution of internship jobs across different areas is shown in Table I, with 754 internship offers in the area of Electrical Engineering.

TABLE I. THE INTERNSHIP OFFERS IN VARIOUS TECHNICAL AREAS

| Technical Area | Number of Internship Offers | |
|---|---|---|
| | *Europe* | *China* |
| Communication, Digital and Interaction Design | 299 | 372 |
| Mechanical Engineering | 251 | 290 |
| Telecommunication Engineering | 223 | 431 |
| Electronic Engineering | 206 | 682 |
| Automation and Control Engineering | 192 | 575 |
| Chemical Engineering | 158 | 159 |
| Electrical Engineering | 143 | 611 |
| Energy Engineering | 123 | 434 |
| Others | 2470 | 3097 |

### C. *Professor level*

#### *1) Supervisor role*

The supervision is critical for the success of graduate students' education [11]. A good supervisor results in postgraduate students with desired personal and professional traits such as the ability to analyze and solve technical problems, the ability to write, and the ability to plan and develop work [12].

The system has implemented a double supervisor approach at the supervisor level. Besides choosing one university professor as college supervisor, every student in this program is assigned one supervisor from industry. Universities invite industry engineers with extensive practical experience from industry to serve as industrial supervisors.

The main responsibility of the university supervisor is to guide students to improve their learning abilities. During the first and second academic year, university supervisor advises students on effective ways to select relevant courses, beneficial learning methods for mastering the required material, and insights on the trends in one's technical area. In the final year of study, faculty will help students choose thesis topics and guide them to complete thesis projects.

The industrial supervisor's main responsibility is to work with students to improve their practical technical skills, develop professional ethics, and improve communications skills. The students are required to spend at least 8 hours per month in their industrial supervisors' workplace. They need to complete a monthly report about their activities in the workplace. The reports are reviewed and approved by their industrial supervisors.

#### *2) Course Instructors*

Many instructors in these two universities have prior industrial experience, and many of them maintain active relationship with number of companies through applied projects and R&D activities, and some even retain positions in industry. The industrial experience ensures that instructors have applied knowledge, which enriches their lectures with real-world examples. The practical problems, that instructors introduce in the classroom, provide students with better understanding of theory as wells as limitations of the commonly used methods for solving practical problems. They also help develop student interest in a particular topic.

In addition, faculty are encouraged to invite experienced engineers from industry to deliver lectures or conduct technical seminars, and to present students with an overview of advanced technology in the specific technical area. They are also encouraged to organize tours of companies. Through these types of activities, students have the opportunity to see the practical application of theoretical knowledge learned in the classroom, as well as to obtain a better understanding of the work environment. If, upon graduation, students have interest in working in these companies, professors can assist them in obtaining interview with appropriate individuals in the respective companies.

### D. *Student level*

After finishing two years of coursework, students have four options to obtain their degrees at the two universities. They can choose to complete either a Project Work, or Internship at each of the universities every half year, as shown in Figure 3.

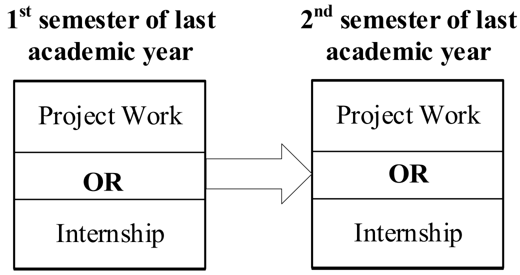


Figure 3 Four options for completing degree

*a) Project Work:* The students are involved in project activity, conducted under the guidance of their two supervisors.

They can choose project which is related to one of the ongoing research projects at their university. In this case, the students will complete their project primarily under the instruction of their university supervisor, while their industry supervisor will provide practical guidance.

In addition to the thesis topics offered by the universities, students can also choose from the topics provided by the industry. These topics originate from the actual industry need, and are reviewed and approved by university to ensure their feasibility and potential for innovation. In this case, companies provide students with necessary equipment and required resources, and student's industry supervisor will play the lead role in the guidance of the project.

*b) Internship:* As an alternative, students may also choose an internship in a company or research institute. In this case the master thesis can be replaced by the report about the internship activity.

The students can find their internships in two ways:

- The students can apply for one of the available internships offered by member companies. Upon a successful interview with the company and approved

*Internship Document* filed with the university, students can start with their internship.

- The students can find company by themselves, in which case the company needs to submit and sign an official document *Internship Agreement* with universities. Upon approval of this document the student can start with internship program.

In order to monitoring the students' internship, university supervisor meet the industry supervisor at least three times, that is in the beginning, mid-term and final. Some students also do the industry project of university supervisor in their internship, so their university supervisor always go to industry to manage the project processing. In the process of internship, university supervisor also attend the team meeting and discuss about the students work with industry supervisor. University supervisor sum up above score to give the students final evaluation.

At the end of the internship, the students are required to provide the final report form filled out by the industry supervisor. The industry supervisors are asked to provide description of the intern's activities, and to describe assigned goals and accomplished results. They also give interns a final evaluation according to TABLE II, which serves as a reference for the universities to make the final assessment of the graduate students.

TABLE II. FINAL EVALUATION TABLE

| **Opinion on the intern's activities** | | ☐ | ***Positive*** | ☐ | ***Negative*** |
|---|---|---|---|---|---|
| | | ***Poor*** | ***Fair*** | ***Good*** | ***Excel.*** |
| Theoretical knowledge: | at the beginning | ☐ | ☐ | ☐ | ☐ |
| | acquired | ☐ | ☐ | ☐ | ☐ |
| Practical Skills: | at the beginning | ☐ | ☐ | ☐ | ☐ |
| | acquired | ☐ | ☐ | ☐ | ☐ |
| Achievement of goals | | ☐ | ***Yes*** | ☐ | ***No*** |
| Overall opinion on the experience | | ☐ | ***Positive*** | ☐ | ***Negative*** |
| **Remark:** | | | | | |

## III. PROGRAM RESULTS

After two cohorts of graduate students completed the program, it was concluded that this program has attained desired results. The findings are based on the anonymous survey conducted among the students who graduated from this program. Some of the questions in this survey are designed by borrowing from the MLSQ instrument [13]. The survey questions are classified in four categories according to overall opinion and relevance of the curriculum, supervisor's effectiveness, and usefulness of projects. The questions and corresponding results are listed in Table III and Table IV. Total of 69 students participated in this survey.

Table III shows the survey questions and corresponding results on students' overall opinion of this program and associated curriculum. In the overall opinion category, 97% of the students agree or strongly agree that they have significantly benefited from this program. Most students think that this program has improved their engineering problem solving abilities (89%) and that it has increased their employment competitiveness (94%). Almost all students (99%) agree that this program is well designed and successfully implemented. The results in the curriculum category indicate that most students (88%) are satisfied with the courses offered in this program. In addition, 35% of the students agree and 55% strongly agree that the courses improve their practical skills.

TABLE III. SURVEY QUESTIONS AND CORRESPONDING RESULTS

| **Survey Question** | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** |
|---|---|---|---|---|
| ***Overall Opinion*** | | | | |
| Overall, I benefited a lot from this program | 64% | 33% | 3% | 0% |
| This program is well designed and implemented successfully | 71% | 28% | 1% | 0% |
| This program helps to improve my engineering abilities | 59% | 29% | 10% | 1% |
| This program increases my employment competitiveness. | 65% | 29% | 3% | 3% |
| ***Curriculum*** | | | | |
| Overall, the curriculum is designed properly. | 49% | 39% | 5% | 7% |
| The courses help me to learn the related theory, application and up-to-date development in the corresponding area. | 59% | 25% | 9% | 7% |
| The courses improve my practical abilities | 55% | 35% | 6% | 4% |
| I am satisified with the performance of teachers | 38% | 43% | 3% | 16% |
| The teachers' lectures are clear and accurate, and practical examples are used properly to illustrate the subject | 30% | 39% | 17% | 13% |
| The projects included in each course are well designed and helpful. | 42% | 39% | 10% | 9% |

Table IV shows some questions related to supervisors and corresponding survey results. It can be observed that most students think that having two supervisors, one from university and one from industry, is excellent (45%) and good (29%).

TABLE IV Survey Questions and Results about Supervisors

| Questions about Supervisors | Excellent | Good | Fair | Poor |
|---|---|---|---|---|
| Compared with single academic supervisor, double supervisor system is: | 45% | 29% | 9% | 17% |
| In increaseing my practical skills and professional ethics, the industrial supervisor is: | 39% | 26% | 22% | 13% |
| The instructions from my supervisor for my problem in study and project are: | 41% | 33% | 20% | 6% |

Furthermore, according to the survey, all the students have participated in at least one project during this program, while majority (68%) have taken part in more than three projects. The results indicate that 79% of students have participated in projects provided by public companies. The results also indicate that vast majority of students (83%) think that provided experiences increase their sense of social responsibility.

In addition, employment statistics have revealed that students who graduated from this program are widely sought after by industry. As Figure 4 shows, 55 out of 72 graduate students found employment immediately upon graduation. The ratio is higher than the average value of electrical engineering students graduated from these two university who had gone through traditional programs.

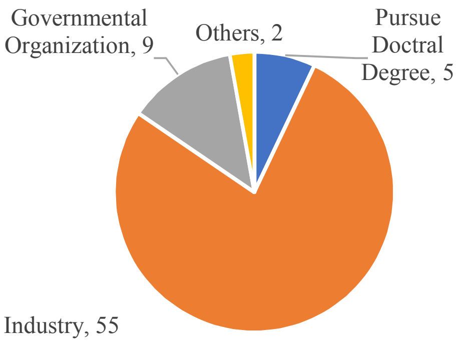


Figure 4 Employment statistics of 72 graduated students

## IV. CONCLUSIONS

This paper presents industry-university cooperation model based on double degree Master program which is designed and delivered by BUAA, Beijing, China and Polimi, Milan, Italy. The essential elements of the program are described and associated experiences are presented in this paper. After the initial two cohorts of graduate students completed the program, the collaborating institutions and industry find the program outcomes to be encouraging and institutions are committed to continue with the program. According to the survey conducted to students involved, more than 90 percent of students think they have benefited from this program. It can be concluded that double degree program based on industry-university cooperation can be beneficial to students in other universities and engineering programs.

## REFERENCES

[1] C Mullenax, "The role of the Master's Degree within engineering education," 2007 Annual Conference & Exposition, Honolulu, Hawaii , pp. 12.1465.1 - 12.1465.5, 2007.

[2] Engineering Accreditation Commission, 2018-2019 Criteria for accrediting engineering pograms, Accreditation Board for Engineering and Technology (ABET), 2017.

[3] S. Cranmer, "Enhancing graduate employability: best intentions and mixed outcomes," Studies in Higher Education, 31(2), pp.169-184, 2006.

[4] Seppo M, Rõigas K, Varblane U. "Governmental support measures for university–industry cooperationcomparative view in Europe. Journal of the Knowledge Economy," 5(2), pp. 388-408, 2014.

[5] https://www.time-alumni.org/

[6] The problem group of the higher education research institute in Shanghai Jiaotong University, "Educating the Next Generation of Engineers for the Global Workshop," Research in Higher Education of Engineering, pp. 24-27, 2007.

[7] W. Otieno, M. Cook and N. Campbell-Kyureghyan, "Novel approach to bridge the gaps of industrial and manufacturing engineering education: A case study of the connected enterprise concepts," 2017 IEEE Frontiers in Education Conference (FIE), pp. 1-5, 2017.

[8] http://old.moe.gov.cn//publicfiles/business/htmlfiles/moe/s3860/201102/115066.html

[9] Culver, M. Steven, "Effective higher education management through collaborative Dual-Degree Programs," Handbook of Research on Transnational Higher Education. IGI Global, 2014. 585-596. Web. 19 Apr. 2018. doi:10.4018/978-1-4666-4458-8.ch028

[10] J. Forces, EIRMA, "Responsible partnering: Joining forces in a world of open innovation," A Guide to Better Practices for Collaborative Research between Science and Industry, pp.1–32, October 2008.

[11] E. B. Petersen, "Negotiating academicity: postgraduate research supervision as category boundary work," Studies in Higher Education, 32(4), pp.475-487, 2007.

[12] Drennan, J., & Clarke, M. "Coursework master's programmes:the student's experience of research and research supervision," Studies in Higher Education, 34(5), pp.483-500, 2009.

[13] Pintrich, R. R, &DeGroot, E. V.,"Motivational and self-regulated learning components of classroom academic performance," Journal of Educational Psychology, 82, pp.33-40, 1990.