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Analysis of the Influence of Undergraduate Research on the Engineering Formation from the Point of View of Students

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Abstract- This paper presents a study carried out to verify how the Undergraduate Research Experience during graduation influences the formation and the decision regarding the professional future of the engineering courses students. In order to reach this goal, a survey was prepared and sent to the students linked to research projects at the Engineering School of the Federal University of Minas Gerais, followed by analyses based on the answers obtained. It can be noticed that most of the respondents believe that the scientific research experience contributes in a positive way to their formation and to their ability to learn, the mentors' approach and mentory was also assessed as positive. However, the majority of the interviewees do not intend to pursue an academic career. It is concluded that the scientific research helped the students to become more critical and allowed them to broaden their knowledge about the topics studied.

Keywords- *Undergraduate Research Experience, Scientific Research, Engineering Undergraduate Students*

I. INTRODUCTION

The Undergraduate Research Experience (URE) goes beyond a research project restricted to the classroom and laboratory environment, it surpasses the academic circle and directly influences the professional, social, and critical formation of the student. Beyond contributing socially and professionally, the URE is the first step towards training future professors, researchers, and even professionals who will enter the working market.

The Scientific Research (SR) is a process that occurs in all areas of knowledge and therefore society depends on it. An example of the SR benefit for society is highlighted in a report by the Institute of Food Research which shows that for every £1 (one pound) invested in research, £8 (eight pounds) is returned to the United Kingdom economy [20].

Using the United Kingdom yet as an example, to stimulate future local economic prosperity, it is necessary for next generations to engage in subjects such as science, technology, engineering, and mathematics. Therefore considerable efforts are being made to encourage students to become more interested in these subjects [7].

In order for such scientific and technological development to take place, it is important that universities stimulate the undergraduate students, from the earliest years of graduation, to have contact with the way to produce knowledge, mainly through participating in research projects, so that they can become skilled, critical and creative professionals**.** Thus, URE for undergraduate students has become a widely recognized and accepted goal of colleges and universities [17].

The university should not only dedicate itself to the formation of specialists. It should also be responsible for creating innovations, conducting high-level SR in different areas of knowledge, in accordance with current and future demands of society and the economy, as well as preparing undergraduate students for carrying out studies based on scientific research [7].

The SR is important for the student to acquire knowledge and put it into practice, carry out applicable research, gain experience and develop social and communication skills [7].

It was observed that there are only a few researches about how the engineering students are related to the SR. The studies conducted in this field encompass, mostly, courses in the area of health or undergraduate and high school students in a generalized way. Therefore, this work can contribute positively to this little explored area.

The first universities emerged in the Middle Age, approximately in the 11th and 12th centuries. According to Bridi [2], the university model of that time showed the predominance of the knowledge transmission, by means of the Faculty of Arts, which was dismembered in two sub areas of knowledge: Letters and Sciences. The concept of university acquired the current molds only in the 19th century, when the German linguist Wilhelm von Humboldt founded the Modern University of Berlin, introducing research into the university institutions together with an intellectual and moral formation of the student [2]. From Humboldt's pioneering approach, it can be observed the origin of the concept of a modern university, which was later applied in most educational institutions.

Until the mid-1970s, the scientific production in Brazil was not widely disseminated and there was no regulatory entity that aimed to foster scientific research in educational institutions. The reality, at that time, was a limited amount of Scientific Research Scholarships (Bolsa de Iniciação Científica - BIC), provided by the National Council for Scientific and Technological Development (Conselho Nacional de Pesquisa - CNPq). In concomitance with the shortage in the supply of SR scholarships, the traditional view of teaching predominated based on the transmission of knowledge by the professor and its possible absorption by the student.

Aiming to support the Scientific Research policy developed in the Institutions of Education through the granting of scholarships to undergraduate students, in 1988 the Institutional Program for Scientific Initiation Grants (Programa Institucional de Bolsas de Iniciação Científica - PIBIC) was established, which began to regulate the granting of scholarships for scientific production.

In 1993 and 2006, two Normative Rules (RN-005/1933 and RN-017/2006, respectively) were created to establish criteria for the selection of students, mentors, and projects.

Thus, the general objectives [2] of PIBIC were established to:

• Contribute to the formation of human resources for research;

• Contribute to reduce in a decisive way the average time of MSc and PhD formation;

• Contribute to reducing regional disparities in the distribution of the country's scientific competence;

• Enable greater interaction between undergraduate and postgraduate students;

• Qualify the best students for postgraduate programs;

• Encourage potential talents among undergraduate students.

The institutional support from policies to foster SR, such as from CNPq (Conselho Nacional de Pesquisa – Brazil) increased the insertion of undergraduate students in the field of research in universities.

The present work aims to verify the effects of the scientific production on the formation of undergraduate students of the Engineering School of the Federal University of Minas Gerais. To this end, it was evaluated the relation between the number of enrolled students and the number of students who participate in a SR project. Also the students' opinions regarding the contribution of the research project in their academic and professional formation, such as its influence on their career's choice were analyzed, together with the relationship between students and mentors.

This work aims to evaluate how the scientific research activity during the graduation influences the formation and the decision regarding the professional future of the engineering undergraduate students of the Federal University of Minas Gerais (UFMG).

II. MATERIAL AND METHODS

To enable an understanding of the influences URE has on engineering students, a survey was prepared and sent via e-mail to the selected students. Following are the questions asked to the students:

- Which department of the School of Engineering did or does your mentor belong to?
- What was the duration of the URE?
- After the URE, which career path do you intend to pursue?
- In your opinion, what can be improved in the URE?
- In your course, is it common for students to pursue URE?
- In the departments linked to your course, is it common to offer SR scholarships?
- If you had the opportunity to give a feedback to your mentor, how would you rate the support and dedication given?
- Evaluate the relevance of the URE to the formation of engineers.
- How did the project developed by you contribute to your professional and academic formation?

All the students, of the Engineering School of UFMG who were linked to SR projects and enrolled in January 2017 in the system of the University's Nucleus of Research Advisory (Núcleos de Assessoramento à Pesquisa - Napq), were selected for submission of the survey. There were 86 responses obtained from students from different courses and departments.

The analyses were performed with the aid of the graphs obtained considering the students' responses.

III. RESULTS AND DISCUSSIONS

A. Target Public

According to Fig. 1, the distribution of the departments to which the mentors of the interviewed SR undergraduate students belong was heterogeneous, with no major concentration in a specific department. The departments with the most students interviewed were: Electrical, Structures, Sanitary and Environmental, Metallurgy and Materials, and Chemistry accumulating approximately 63% of the total answers.

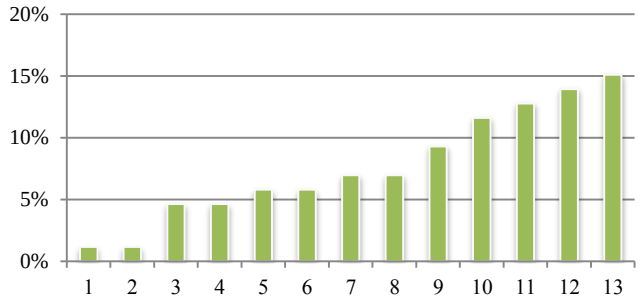

Figure 1. Percentage of respondents by department. 1 - EHR - Hydraulics and Hydric Resources; 2 - DENU - Nuclear; 3 - DEP - Production; 4 - DETG-Transport and Geotechnics; 5 - DEMC - Construction Materials; 6 - DEMIN - Mines; 7 - DELT - Electronics; 8 - DEMEC - Mechanics; 9 - DEQ - Chemistry; 10 - DEMET - Metallurgy and Materials; 11 - DESA - Sanitary and Environmental; 12- DEES - Structures; 13 - DEE - Electrical.

B. Duration of the URE

From Fig. 2, it is observed that 76.5% of the students stated that their URE had a minimum duration of six months and a maximum of two years. Approximately 45% of the URE lasted from six months to one year, while 31, 8% lasted from one to two years.

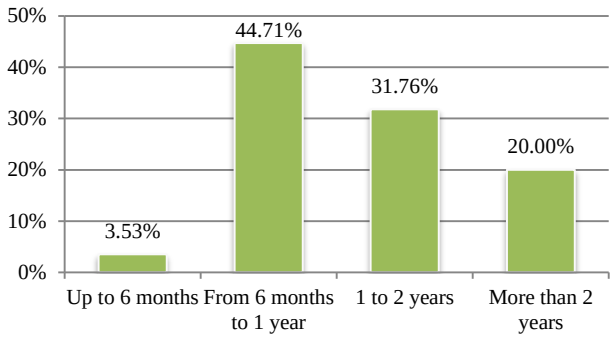

Figure 2. Duration of the URE of the interviewed students.

A reasonable amount of time is necessary for the student to truly understand the research project that they are involved, so they can in fact have gains in terms of learning. Therefore, it is important for universities to encourage students to stay longer in these programs, for example, involving students in research at the beginning of graduation [5][13].

Similarly, Linn [8] describes that the studies that measured the understanding of scientific practices report little or no gain up to 1 year of URE. Students who have spent more than 1 year in a URE often learn new methodological techniques, collect their own data and interpret it, such as formulate new research questions.

C. Relevance of the IC Project

The graphs of Figs. 3, 4 and 5 show that the majority of students interviewed believe that URE contributes positively to the learning and formation of engineers. The scientific research activities develop students' intellectual potential and expand their creativity [5][7].

In general, studies reveal that students positively assess the URE for professional and academic formation, supporting the bibliography [12] [15] [17].

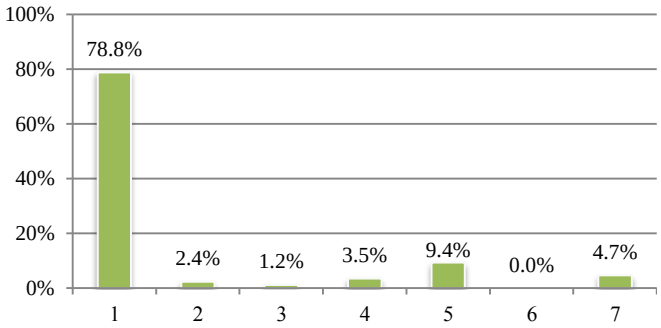

Figure 3. The influence of URE to the formation of engineers in the interviewees' opinion. 1 - It greatly helped my formation and my ability to learn; 2 - I learned more in the URE than in the course, because the subject was more interesting; 3 - I am not interested in SR activities; 4 - I think it does not influence much in the formation of the engineers, it is complementary; 5 - In fact, there is not enough internships avaiable; 6 - It causes the student to waste a lot of time with these activities instead of dedicating to the course; 7 - Another.

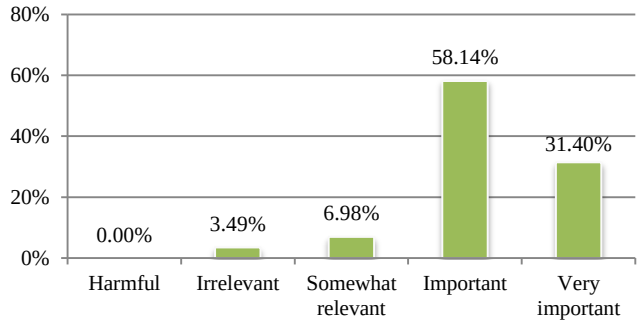

Figure 4. Effect of URE on the formation of engineers in the interviewees' opinion.

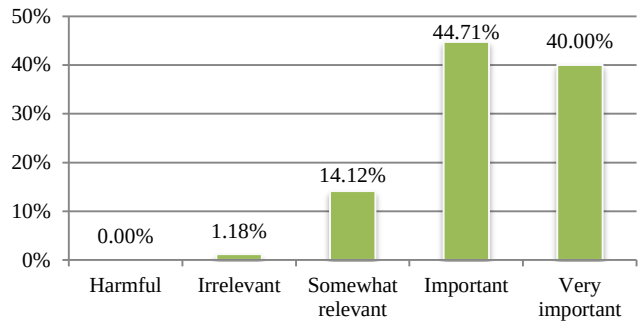

Figure 5. The contribution of the URE to the formation and academic life, according to the interviewees.

Some the advantages of the URE for students are: development of oral skills, written ability and differentiated manual skills [3], critical reading of bibliography [3][13], loss of fear when faced with adversities[4], autonomy for the interpretation of facts[3][5], understanding of research processes [5][13][15], development of communication skills [13][14], technical skills (equipment utilization and specialized techniques) [13][14], computer skilss [13], teamwork in a independent way [13][15] and statistical skills [13], in addition to improving ability to competently exercise activities related to their profession [14][18]. It can be concluded, therefore, that URE is considered to be an extremely important component for the university curricula [17][19].

When questioned about the relevance of the URE to their formation as engineers 9.4% of the respondets answered "In fact, there is not enough internships avaiable", suggesting that they would choose instead to be working at private companies if there were more internships avaiable (Figure 3). This indicates the interest of the students in entering the working market, which is better evidenced in Fig. 6.

D. Career Pretension

The URE offers an opportunity for students to be in contact with the research and with professors, what can encourage them to identify with the area and pursue an academic career. New researchers learn to practice science by engaging in SR projects [4]. However, according to figure 6, it is possible to observe that, although 99% of the interviewees had experienced the URE, 54% of them intend to enter the working market, whereas 27% have the pretension to follow an academic career in Brazil or abroad. The interviewees who answered "Other" were whether undecided, intending to open an own business or to work in another area of their formation.

In contrast to this study, a survey conducted with malaysian medical students concluded that the URE lead them to choose careers as clinical-scientists [15].

It is plausible to emphasize the ideas of Sadler [13], who concluded that URE contributes to confirm the pretension of those students, who already were interest before the URE, in pursueing an academic career at a postgraduate level. Therefore, the URE is not considerably responsible for a chenge in the professional choice.

Student participation in SR is widely valid to encourage them to advance degrees and seek for careers in science, technology, engineering, among others [12]. In addition, URE is considered the best way to attract professionals to academic careers. This is the clearest goal of SR projects, but it is not the only one [18]. Thus, the results obtained can not be considered negative, since the SR, in addition to formation of researchers, assists in the training of qualified professionals the working market. It is possible to affirm that "it is a mistake to admit that SR exists exclusively to form a scientist. Besides that, it is very positve whether the student makes a career in the academic area or chooses a professional career. In both ways the student will enjoy a better capacity for critical analysis, intellectual maturity and, certainly, greater discernment to face their difficulties."[3]

Along this same line of thinking, Oliveira [10] concluded in his research with medical students that a good professional should have the ability to think scientifically and use the scientific method, since he needs to be always updated, seeking new information and knowledge.

Siraj [15] concluded in his study that mentory was one of the most influential factors in students' interest in academic activities after graduation.

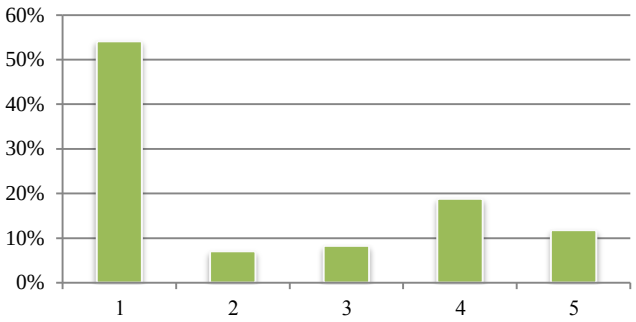

Figure 6. Responses related to career pretension after graduation. 1 - Work as an engineer in the area of my course; 2 – Pursue a career as a Public Servant in areas related to my formation; 3 - Work as a researcher in Brazil or abroad; 4 - Work in the academic area as a professor and researcher;

E. Suggested Improvements

From Fig. 7, it can be seen that the students are dissatisfied with the number of scholarships offered for SR projects, which indicates that the demand and the time of permanence of the students could increase if more scholarships were made available. The lack of government incentives to education makes the number of scholarships much smaller than the number of students seeking for URE, so they can only enter the SR project as volunteers. Because of this lack of grants, many students who are unable to remain in college without a job to meet their expenses are thus deprived of the URE. The world practice shows that studies at universities are grounded in science. Thus, science should have greater importance and investment in order to guarantee a well-founded education. In addition, it is known that there is a return of this investment to

the economy, because the research generates several useful results and discoveries that can leverage the economy [7].

In a study carried out by Pinto [11] with students of the dentistry course, it was concluded that students who won a SR scholarship presented a twice-higher prevalence of seeking an academic postgraduate program than volunteers. On the other hand, Görgens, in a research with medical students from UFMG, obtained the same average of publications when comparing the scholarship holders and the volunteers [6].

As is well known, SR has great importance for engineering, which demands innovative resources to keep pace with the working market. However, research needs to be prioritized, so that innovation and development in the engineering sector are maintained. It is important to know about student participation in URE as they put their skills towards the success of the research [4].

Again, the students' search for the private initiative is shown in figure 7, with 31.4% of the answers, students believe that there should be greater involvement of companies in the projects of SR. This response reinforces what was observed in figure 6.

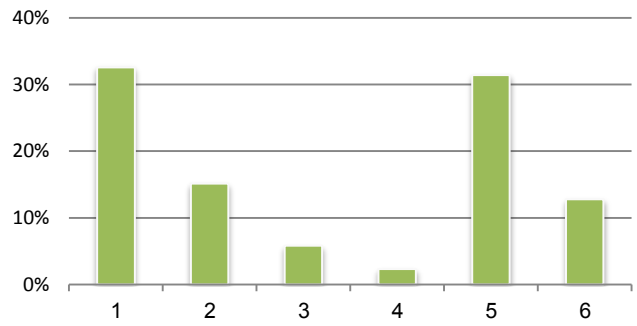

Figure 7. Suggestion for Improvements. 1 – To offer more scholarships; 2– To increase the proximity between mentors and students; 3 – To demand more from students to improve the work; 4 - Increase the flexibility of activities; 5 - To get more involvement from the private initiative; 6 – Other.

From the students who answered "Other", most believe that several of the mentioned factors should be improved, aiming for higher scholarship amount, greater criterion regarding the project theme, greater mentory and assistance at the beginning of the project and, more autonomy. The SR should be developed in a way that also involves students in complex activities that stimulate their reasoning with data analysis, hypotheses and questioning. Otherwise progress in reasoning practices can become limited [13].

F. Students' search for the URE

According to the interviewees, it is common for students in their courses to search for SR activities. A similar result was found by Oliveira [10] in his research with medical students. According to the author, only 7% of the students do not have an interest in research, evidencing the students' expectation of being involved in SR and URE during graduation.

According to Oliveira [10], there are many reasons why some students do not seek for an URE, some of them are lack of interest, lack of qualified or motivated staff, lack of material conditions, lack of institutional stimulation for research.

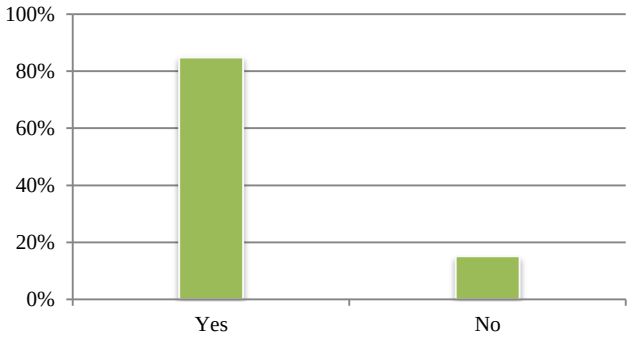

Figure 8. Student's search for the URE, according to the opinion of the interviewees.

G. URE Disclosure

A positive response to the department's encouragement to SR is shown in Figure 8, since most of the students take initiative to look for mentors, when interested in SR. However, a large portion thinks that professors do not comment enough about researches and that SR is not well disclosed, showing a disparity with the disclosure of scientific research.

In a study carried out with medical students, it was pointed out that the main reason that make it difficult for medical students to perform SR activities is the lack of institutional stimulation [18].

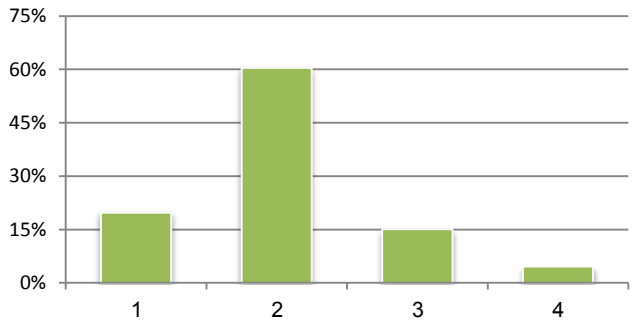

Figure 9. Disclosure of the SR in the opinion of the interviewees. 1 - Yes, the selections are published; 2 - Yes, students look for mentors when they have interest; 3 - Nothing is disclosed about SR; 4 - Professors do not comment about SR.

H. Mentory's Feedback

According to Figure 9, approximately 80% of the respondents evaluated the support and dedication of the mentors as excellent and very good and the smallest part as

bad. The mentor's relationship with students is extremely important to increase their interest in SR, leading them to improve research skills. The Figure10 show a positive result, in this thinking bias, because it is very important to deepen the scientific knowledge of the student, to educate his critical thinking, and to encourage the work of scientific research [7][11][18].

The approach of the teacher to the student is beneficial for both parties, because this contact is not restricted to discuss aspects of the project developed, the close relationship with the mentor contributes to the exchange of information and personal experiences.

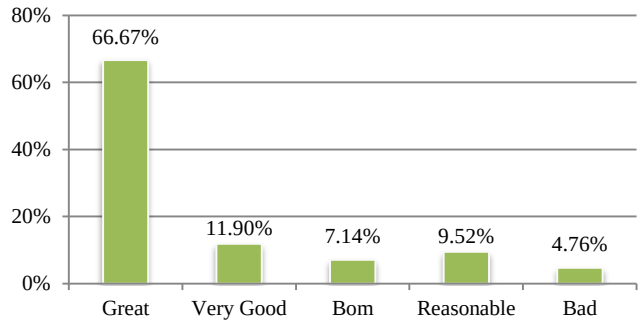

Figure 10. Interviewer's opinion regarding the mentor.

A similar result, Siraj [15], found in his research with a medical student in Malaysia, where 80% of the respondents evaluated their counselors positively.

The most serious inaccuracy of a URE is the disappointment the student may face. Caution is needed in choosing the mentor, by not only analyzing the curriculum or friendliness, but rather working with Professors who really will contribute to their personal and intellectual growth [3].

Yeoman [20] conducted a study through surveys sent to students and teachers. The answers were compared and there were significant differences in relation to the influence that the URE exerts on the students learning process and choices. It can be noticed that the teachers underestimate the influence that the URE exerts on the students when compared to what the students think about the same topic.

In addition, the professor's approach to research is substantial. K. Taber [16] argues that professors should be able to interact in the classrooms, together with researching about relevant professional issues and problems. Also, it is expected from a mentor to be open, curious and not omniscient, therefore constantly seeking for new knowledge, since this posture contributes to a good relationship with the student raising the interest in SR projects.

The undergraduate students interact more during SR with postgraduate students, mainly because they have more time available to assist them. However, this orientation tends to focus more on technical aspects, not stimulating complex skills such as logical thinking, knowledge, and problem-solving [8].

A reality pointed out in other studies is that many students participating in a SR project are converted into cheap labor [1][3], which can contribute to students' dissatisfaction with the mentoring and consequently to the project developed.

IV. CONCLUSIONS

According to the analyses carried out, it can be concluded that the interviewed students consider that the URE influences in a positive way their academic and professional formation, it was also assessed as positive the mentors' approach and mentory**.** However, these evaluations did not significantly influence the students' choice to pursue a career as a researcher, with the majority of respondents claiming to enter the working market after graduation.

It could also be noticed that the students of these courses generally have an interest in participating in research projects and that, in most cases, they take initiative to look for the professors who carry researches of their interests. As suggestion for improvement of the URE, the respondents evidenced the increase in the number of SR scholarships, and a greater involvement of private initiative in the projects.

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