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Simulation with system dynamics on university student research

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ABSTRACT

Currently, student research at the university under study is carried out from the first semesters until the student graduates, but it is necessary to make adjustments to its guidelines that include student research within a teaching-learning process. The objective of the research is to propose a model of student research, using causal diagrams and forrester diagram; then carry out a simulation of the projection from 2021 to 2026 with the variables, students, quality teachers in the research, completed work for publication in journal or conference; and thus index in Scopus or Web of Science. Besides, in the methodological part, the systems dynamics method was applied, based on the systemic approach. The research work is predictive, which was carried out with the Vensim software, obtaining as a result of the simulation, an increase in the production of complete Works by the students; where in 2026 around 300 articles will be published by the students. In addition, there will be about 12 full-time quality research professors and approximately 6,000 students in 2026. The conclusion reached in the research is that the model helps the authorities make decisions appropriately according to the forecasts made in the different scenarios made with the Vensim software.

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1. INTRODUCTION

Student research is carried out in the different universities of the world. At the beginning of the creation of the universities, the Humboldtian model was called, to the universities that prioritized research. In Russia, students carry out project-based investigations by developing their investigative skills [1], [2]. In Latin America, Brazil is the country that most develops research at the undergraduate and postgraduate level [3]. One of the universities is the University of Sao Paulo. Also, the University of Chile as the national and private; the University of Buenos Aires (UBA); the National Autonomous University of Mexico (UNAM), also promote the research. In Peru, research is just beginning to develop with the proposal to create the Ministry of Science and Technology. In addition, student research in universities is being promoted by the National Science and Technology Council (Concytec), which in the last regulation approved in 2021, establishes that the undergraduate student can participate with their registration certificate, to be recognized as a research student; where it must reach a minimum score established by the regulations. But, university teachers must also investigate, to radiate with the students in their classes, where they will also be called research teachers if they classify in one of the 7 categories, established by said regulation. In general, the universities in Peru were oriented more by an academic education, than by research; where currently universities are adapting to comply with university law and thus graduate and optionally get accredited.

In the educational model of the university under study, one dimension is the investigative part. The university has its research center, made up of senior and junior researchers, who are graduate students and experienced researchers. University law 30220, that universities must develop research; that means that the teacher must also investigate [4]. This will allow working with students in the different research lines of the university's study programs.Within the curricular plan and as part of it the study plan, there are courses in the first semesters as a basis for formative research, such as courses in interpretation of texts, writing and argumentation, academic research. Likewise, there are courses that serve as a bridge, such as statistics; then take courses in the last 4 semesters, such as scientific research method, thesis seminar, thesis 1, thesis 2 in the different careers. Student research is important since it allows them to develop their investigative skills, to solve problems that the student can do in the company, or in society; thus, students can advance by developing their investigative capacities, with the support of the university [5]. Student research can also be reflected in the course of integrative projects, since it allows to use the knowledge acquired during the previous semesters;this should be proposed in the new curriculum redesign. Formative research allows students to develop in research from the beginning of their entrance to the university, until they graduate [6].

According to Ocek *et al.* [7], research in undergraduate medical students had been carried out with basic theoretical classes in research, developing in groups. But, they did not emphasize doing, that is, through practice, where the student should first investigate, then publish and disseminate it. Surveys and interviews were conducted to obtain information and make improvement, as feedback. The students, if they were motivated for the investigation, but, lacked more support from the authorities. Mugruza-Vassallo [8], analyzes student research, differentiating that not all students will be researchers. Some will have that spirit of being able to inquire and others are oriented towards professionalization. In addition, it suggests that the courses, such as theses of the last semesters, must be carried out with the support of a tutor. Also, it analyzes the curriculum, so that students can have a base from the first semesters. Students must take this knowledge, already established, by men of science so that they can use it in their investigation, and thus contribute and contribute to society. In addition, the students who like to investigate must form a research society for the university. Student research [9], should begin with the writing. Correctly carry out the writing of the article, the syntax, spelling, typography, organizing the ideas, to have a logical coherence from beginning to end. On the other hand, the formative research of the students begins from the first academic semester, with writing courses, text interpretation, then in the last semesters with thesis courses [10]. Thus, students are developing in their investigative capacities. This allowed them to publish articles, with the advice of a research teacher. Also, Andrade-Arenas *et al.* [11], in research work, it analyzes from the curricular plan, based on the investigative dimension, carried out by students and teachers. To do this, they train teachers, so that they can guide their students in formative research, and thus, publish articles.

In summary, the authors agree that the students' research allows the development of their investigative capacities, to produce reports, such as monographs, articles, theses. However, greater clarity is lacking in the research training of undergraduate students, through the formation of a research circle. What has been analyzed makes the research work under study capable of investigating groups made up of students in the research lines of the university, guided by quality research teachers.

The objective of the research is to make a proposal model for the formation of student research through a causal diagram, at the University of Sciences and Humanities. Then, to carry out a simulation of the proposed model with the Vensim software in the period from 2021 to 2026. This proposal is based on the experience that is being carried out in the university's research with the students, since it is part of the educational model of the university. Likewise, the research experience on the part of the teacher is important, as well as the disposition of the student, to later obtain a quality publication [12]. The systems dynamics method [13] was applied, which is based on the systemic approach. This method sees the system under study as a whole; where its elements are concatenated with a defined purpose [14]. The method predicts the behavior of the system [15]. The investigation is structured by sections. In section 2 the literature review was carried out; in section 3 the method; in section 4 the results, section 5 discussions and finally in section 6 the conclusions and future work.

2. METHOD

The research is quantitative, explanatory, predictive in scope, with a non-experimental, cross-sectional design. The object of study is student research. Besides, the unit of analysis are students from the University of Sciences and Humanities; all this is done through simulation in a given time, using system dynamics.

2.1. Analysis

2.1.1. Causal relationship

Positive causal relationship: a causal relationship is positive, when one variable influences the other variable, directly proportional [16]. For example from Figure 1 shown, it is a positive causal relationship, where the student variable influences the graduate variable [17] in a positive way; that is, more students will have more graduates, or fewer students will have fewer graduates, this is called directly proportional, that is, if one increases the other increases or if one decreases the other also decreases [18]. Negative causal relationship: a causal relationship is negative, when one variable influences the other variable, inversely proportional. For example, in Figure 2, the more graduates, the number of students decreases, that is, if one increases, the other decreases, or if the other decreases, it increases [19].

Figure 1. Positive causal relationship

Figure 2. Negative causal relationship

2.1.2. Loop

Positive loop. A loop is called positive, when its causal relationship has a positive even number in its polarity. It is placed in the center of the graph, the positive sign or a letter R for reinforcement; means the system is unstable [20]. In Figure 3, it can be seen that there are 5 variables and their polarity are all positive. Therefore, we can say that the loop is positive, and the system exhibits instability [16]. Negative loop. A loop is called negative, when its causal relationships are an odd number of negatives in its polarity. In Figure 4 shown, they have 2 variables, and their polarity has a negative sign. It can be said that the loop is negative, because it has an odd number of negative in its polarity. It is placed in the center, the negative sign or the letter B of balancing, and that means stability in the system [21].

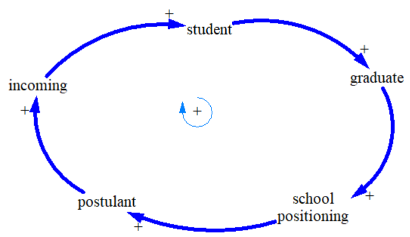

Figure 3. Positive loop

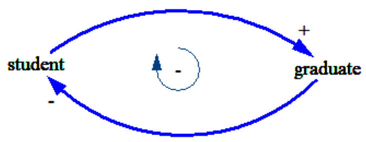

Figure 4. Negative loop

2.2. Design

In Figure 5, 3 positive loops are shown, which is represented by the letter R1, R2 and R3 to differentiate it. R1 is represented by 7 variables, where all its polarities are positive. Therefore, it will be said that it is an unstable system, because it is a positive loop. The R2 is made up of 5 variables, where their polarity are all positive; it is said to be a positive loop. And R3, for 10 variables, where the polarity of all of them are positive; then it can be said that it is a positive loop. In addition, it also shows 3 negative loops, which is represented by sign B1, B2, B3. Loop B1 is represented by 3 variables, where 2 are positive and one is negative; In other words, it has an odd polarity, therefore it is a negative loop and expresses stability in said system. The B2 loop has 2 variables, where one of them is positive and the other is negative, also odd, therefore it is negative; loop B3 represents the same as above.

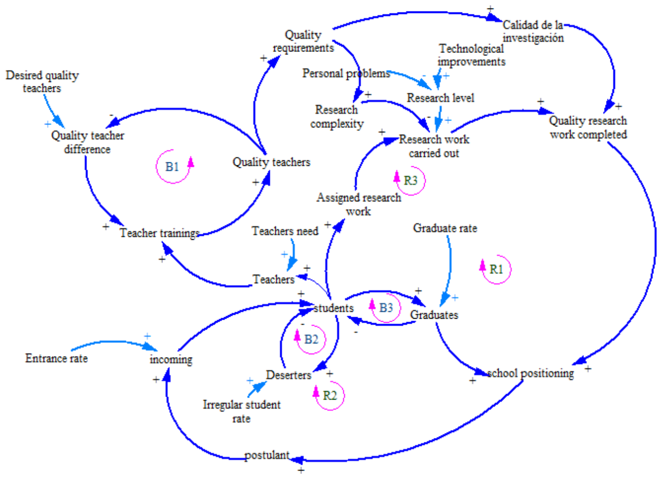

Figure 5. Student research causal diagram

3. RESULTS AND DISCUSSION

3.1. About the causal diagram and forrester model

The causal diagram allows us to have a broad vision about the research of the students and their relationship with the teachers and the other variables. This allows to analyze when the system is stable and when it is unstable. The model shows stable systems, that are represented as positive loops and unstable systems that are represented with negative loops. Positive loops also called reinforcement loops must be taken into account with enough analysis criteria, since their growth can generate an explosion in the system under study; The causal diagram allows us to have a broad vision about the research of the students and their relationship with the teachers and the other variables. This allows to analyze when the system is stable and when it is unstable. The model shows stable systems that are represented as positive loops and unstable systems that are represented with negative loops. Positive loops also called reinforcement loops must be taken into account with enough analysis criteria, since their growth can generate an explosion in the system under study. However, in the model, systems with negative loops are observed, which is balanced and counteracts the positive loops, compensating for their stability; This is why it is also called stable systems. In the forrester diagram of Figure 6 shown. It was analyzed using levels that are students, quality teachers and cuminate reasearch work. These levels can increase or decrease depending on the inflow or outflow you have. Training, incoming, research work carried out is observed as input flow; this causes their levels to rise. In addition, the outflows are: graduates and deserters. Likewise, we also have auxiliary variables that directly or indirectly influence the system under study. Table 1 shows the formulas for the variable level, the inflow and the outflow, as well as the auxiliary variables, these formulas are entered in the forrester diagram of Figure 6 and processed in the Vensim PLE 9.0.1 software. In addition, Table 2 shows the data entered in the Vensim software. Internally, the software works with numerical methods where one of the methods that works internally is Euler's method, which is a function of time.

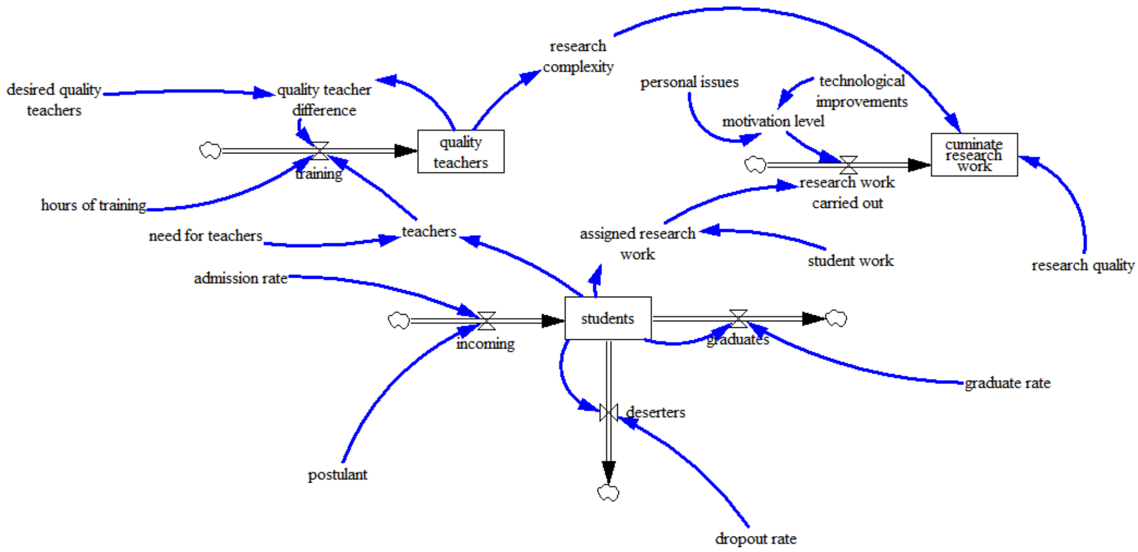

Figure 6. Forrester diagram of student research

Table 1. Formulas

Variables	Formulas
Variable level	- Students= incoming-deserters-graduates.
	- Quality teachers= training.
	- Cuminate research work= research quality*research complexity*Research work carried out.
Variable flow	- Incoming = postulant * admission rate.
	- Deserters = students*dropout rate .
	- Graduates = studentes * graduate rate.
	- Training = (teachers-quality teacher difference)/hours of training.
	- Research work carried out = assigned research work * motivatión level.
Auxiliary variables	- Teacher = need for teachers*students.
	- Quality teacher difference = desired quality teachers - quality teachers.
	- Motivatión level = 1-(personal issues + technological improvements).
	- Research complexity=0.25+ (quality teachers*0.03).

Table 2. Data

Number	Data
1	- Dropout rate = 0.125
2	- Graduate rate= 0.02
3	- Postulant = 400
4	- Admission rate = 0.05
5	- Meed for teachers = 0.6
6	- Hours of training = 80
7	- Desired quality teachers = 15
8	- Personal issues = 0.3
9	- Technological improvements = 0.3
10	- Student work = 6
11	- Research quality = 0.07

3.2. Scenario analysis

3.2.1. Quality teachers

According to Figure 7, from 2021 to 2026 there is a growth in the number of quality teachers. Having the projection of about 12 full-time teachers who have the profile of researcher teacher, that is, they have all the characteristics of a quality teacher in research, as well as in the teaching strategy, being a guide and example for students are motivated to do their research. This is achieved by looking for the research teacher who must have the following achievements: i) have publication in indexed journals with students; ii) have publication in journals of quartile 1, in Scopus or Web of Science; iii) motivating and empathetic teacher; iv) teamwork with students; v) innovative projects carried out with students; vi) be a mediator in the teaching-learning process; vii) Have experience in reviewing articles in Q1, Q2, Q3 and Q4 quartile journal; viii) participation with achievements in competitive funds; ix) be a jury of undergraduate and postgraduate theses; x) be an undergraduate and graduate thesis advisor.

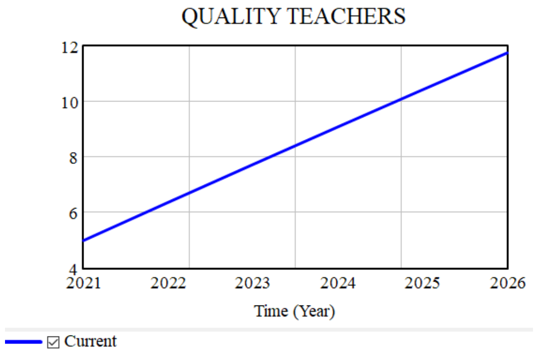

Figure 7. Quality teachers

3.2.2. Students

In the scenario in Figure 8, the growth of the students is shown. Where in 2021 there were about 2,000 students, and by 2026 about 6,000 students. Therefore, new strategies must be developed in the research area, for this new projected context. It is proposed to do the following: i) redefine the student research policy; ii) organize the circle of student researchers; iii) the creation of integrative projects in the new curriculum; iv) student participation in national and international projects; v) participation of students in solving social and business problems in multidisciplinary and interdisciplinary teams; vi) promote the creation of research seedbeds from the first semesters; vii) promote knowledge networks in research, interuniversity; viii) update the research lines; ix) train student leaders in research.

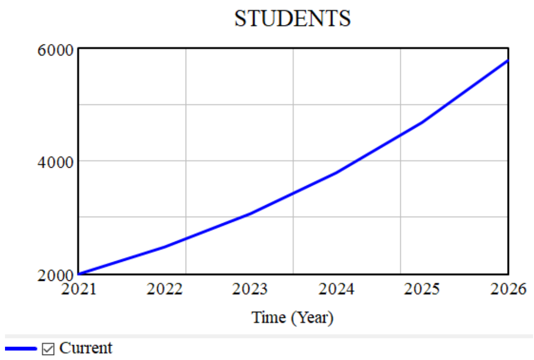

Figure 8. Students

3.2.3. Research work completed

According to Figure 9, from 2021 to 2026, the projection that students must send is 300 articles accepted in journal or conference, indexed in Scopus or Web of Science. In that sense, The research work must be carried out as a team between teachers and students to achieve the objective that is the publication and acceptance of articles. Likewise, students are being trained in lines of research and how to write an article. In addition, courses that are oriented towards research have been placed in the university's curricular plan from the first to the tenth semester. For the works to be published successfully, the following must be fulfilled: i) be supported with first-rate laboratories; ii) have all the adequate infrastructure for research; iii) have constant training to be able to be successful in the completion of the articles; iv) the teacher in the classroom must teach with adequate method and techniques in articles sent to journal; v) student research must be reviewed by their research teachers before submitting the finished article; vi) students choose one or two lines for research; vii) students must learn the writing in the correct way; viii) students must know the structure of an article; ix) students must know how to search for information from reliable sources; x) know each section of an article according to the magazine to send; xi) knowledge of english; xii) sending the article in teamwork.

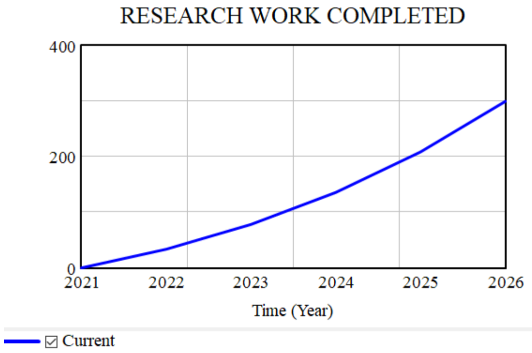

Figure 9. Cuminate research work

3.3. About the method

The systems dynamics method is based on holism, since in its causal diagram it integrates all its exogenous and endogenous variables, as well as the levels integrated by causal relationships. In other words, it analyzes it as a whole and its relationship of its components. In addition, it studies the behavior of a system in a certain time. It also makes a prediction by doing a simulation [22] with the vensim [23], software, depending on the time that can be days, years among others. Systems dynamics applies systemic models and then the transition can be made to the forrester diagram, which can be used by some software such as Vensim [24], [25] Stella among others. It is analyzed with the different scenarios that can be represented to predict the behavior of the system under study. In the research work, the systems dynamics method allowed us to understand the reality of student research and made it possible to project the dissemination of student articles and the quality of teachers who play the role of mediator.

The model proposed through causal diagrams that is based on cause and effect; allowed to see the causality between the variables selected for the object of study. The proposal is aimed at students developing their research skills, with the mediation of a teacher who has the profile of a helpful leader and knows the research environment, so that he can guide his students. However, not all students have that research orientation, but rather professionalizing. It is there that it is concluded that some students will develop their investigative capacities more than others. On the other hand, the research line of the university must be updated each time in the different professional schools of the university according to the trends and contexts that are presented.

The formative research proposal is developed at the university from the first semesters until the students graduate. The research program is currently made up of 3 programs. The first program covers the first three semesters, where the student learns to interpret, write the monographs correctly, as well as know how to read and learn some techniques that allow him to advance in this first stage. Likewise, in the second program it takes courses from statistics, research to academic These courses make students seek information, as well as process information. However, there is a limitation, since there are teachers who still need to be trained in the use of statistical software such as the SPSS for information processing. And finally the program 3 where the student takes courses in scientific research method, research seminar, thesis 1, thesis 2 where the student makes his article and in the thesis begins to develop more extensively.

4. CONCLUSION

In the research work, it is concluded that formative research must be developed with research guidelines by the university, so that in this way they have a north in student research. Besides, the research tutors must continue to develop their research skills, in order to continue guiding their students. On the other hand, the systems dynamics method allowed a holistic view of the problem, where it was possible to analyze the different variables under study and their interretion through causal diagrams. The modeling of the causal diagram and the forrester diagram could be executed using the vensim software, obtaining encouraging scenarios, the forecast is that you will see publications by the students under the guidance of quality teachers, in research.The forecasts made in the different scenarios will allow making decisions appropriately by the university authorities. It is suggested that a circle of student research hotbeds be formed, where students can select the line of research to investigate. It is recommended to give all the necessary conditions for student researchers such as computers, laboratories and funding for research projects.

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