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A Model of Interdisciplinary Approaches with Math, Research, Robotics, and Forensic Sciences: The UNE R^3-STEM Project

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Abstract: The UNE R^3-STEM project at Universidad del Este (UNE) currently Universidad Ana G. Méndez (UAGM), Carolina Campus, was designed to increase the *r*ecruitment, *r*eadiness, and *r*etention of high school students in STEM career pathways. UNE's R^3-STEM addresses these 3R's through two collaborative interventions: 1) High School to University Bridge Program; and 2) Faculty Curriculum Development Program. A model was designed that integrates three approaches: increase recruitment, readiness, and retention of high school students in STEM. Approaches that are curricular integration and providing both academic and non-academic support through extracurricular activities. The recruitment (R^1) consisted of recruiting faculty from different disciplines, peer-mentors, and high school students. In addition, faculty was trained in various evidence-based teaching strategies. Peer mentors also were trained in different aspects of mentoring and leadership. For readiness (R^2), high school students participated in a comprehensive training that includes curricular and extracurricular aspects. Retention (R^3) in this project was defined as increasing the number of high school students enrolling in STEM programs. This project provides a multi-level collaborative support system that begins in the recruiting, training phase and continues until the students' progress in STEM careers. In this process, the synergy of the academic and non-academic support is prioritized to maximize the academic performance of STEM students in an integral manner. The development of the model made possible to create a favorable environment for the active insertion.

Key-Words: student retention; interdisciplinary; robotics; forensics; STEM.

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1. Introduction

The UNE R^3-STEM project at Universidad del Este (UNE), currently Ana G. Méndez University (UAGM) Carolina Campus is a collaborative effort with the objective of maximizing student development by increasing the recruitment, readiness and retention (R^3) of Hispanic high school students interested in pursuing careers in Science, Technology, Engineering and Mathematics (STEM). The project addresses the critical need that exists in both Puerto Rico and the United States to increase the participation of underrepresented minorities in scientific and technological careers. UNE R^3-STEM achieved its objective through two innovative collaborative interventions: 1) a High School (HS) to University Bridge Program (HS-UBP) to increase the recruitment of high-need HS students and their readiness to enter STEM academic programs; and 2) a Faculty Curriculum Development Program (FCDP) that focuses on increasing student retention by improving learning outcomes and student engagement.

The first intervention is the HS-UBP, in which underrepresented minorities high school students interested in STEM careers receive academic and non-academic support. These underrepresented minorities are economically disadvantaged and first-generation college students who are academically under-prepared, with limited English proficiency, and lack of family culture related to college attendance. The academic support consisted of a dual-enrollment program in which students can accumulate up to six college credits by completing two courses: Basic Mathematics (MAGS 101) and Introduction to Research & Information Literacy (INGS 101). Both courses integrated robotics and forensic science activities into their curriculum. In addition, the mathematics course was enriched with the learning and instructional platform EducoSoft™.

The HS-UBP was complemented by non-academic support thru mentoring and tutoring services. For the second intervention, Mathematics, Engineering, Forensic Sciences and Research faculty were trained in evidence-based teaching practices and educational research to improve teaching-learning processes for students in STEM. The multidisciplinary faculty worked together in the curricular integration of STEM activities within the impacted courses.

The curricular integration facilitated a dialogue among disciplines that resulted in an interdisciplinary team. Both interventions were embedded in a Model of Interdisciplinary Approaches with Math, Research, Robotic and Forensic (IMaR^2Fo). The model and its phases are described in depth in the following sections.

2. IMaR^{2}Fo Context

It is vital that universities offer innovative responses to the demands of a globalized world, where the accelerated development of technology and communications is observed. In addition, the integration of knowledge is necessary to find solutions to 21st century problems. According to Ander-Egg (2009), the integration of different disciplines demands new ways to understand a problem since one of the basic ecology principles' states: "everything is related to everything, nothing happens in an absolutely isolated way and nobody acts in complete independence" (p.268). For this reason, the IMaR^{2}Fo model shows three approaches to increase the retention in the STEM community. These are curricular integration, academic and non-academic support.

2.1 Curriculum integration: Interdisciplinary Approaches

Interdisciplinarity is an intermediate level of integration in which the transfer of methods occurs from one discipline to another (Piaget, 1979 & Klein, 2008). From the perspective of the educational process, interdisciplinarity is the exchange between disciplines to approach a problem or object of study from another area of knowledge. The tendency in recent educational paradigms is to promote teamwork across disciplines while respecting the importance that each of the disciplines contributes to the educational process. In addition, as Morin (2002) stated in the Seven complex lessons in education for the future, it is crucial that we work as a team to achieve mutual understanding in all dimensions. Therefore, within the UNE R^3-STEM project the interaction among the multidisciplinary faculty was prioritized to enhance the curricular integration through interdisciplinary approaches.

2.2 Academic Support: Dual-enrollment

Studies have shown that dual-enrollment programs have a positive impact in post-secondary education by addressing poor academic preparation and low graduation rates of high-school students (An, 2013). A study from the National Research Center for Career and Technical Education conducted by Mechur, Calcagno, Hughes, Wook and Bailey (2007), showed that high school students who participated in dual-enrollment programs had significantly higher cumulative college GPAs three years after high school graduation when compared to peers who did not participate in dual-enrollment programs. In addition, they earned more college credits (indicating progress toward a degree) than non-participating peers.

2.3 Non-Academic Support: Mentoring and Extracurricular Activities

To promote student success in STEM, it is critical to provide not only academic interventions but also include non-academic activities that support the integration of cognitive, social, and cultural aspects in educational environments to motivate students to achieve their career goals. A conceptual framework of effective mentoring and motivation has been successfully implemented in different student development programs (Good, Colthorpe, Zimbardi & Kafer, (2015), Nora & Crisp (2007), Keller (2010). This framework includes four mentoring domains: knowledge and academic skills, role modeling, emotional support, and career guidance; and four motivation factors: attention, relevance, confidence, and satisfaction.

To this extent, the UNE R^3-STEM project is structured on Tinto's theory for student retention (1993) which is composed of three dimensions: a) *Academic*: Promotes strategies for the student's academic success; b) *Student*: Provides advice for the successful achievement of academic goals; and c) *Administrative*: Manages and tracks students to facilitate proactive decision-making. The project is also enriched with Seidman's retention formula (2005), which uses early identification strategies and timely, intensive and continuous intervention. In addition, the institutional Retention Office offered support to this project by: 1) integrating STEM Faculty as student's advisors; 2) conducting workshops and services on issues of retention and academic success; 3) establishing individual education plans and monitoring the progress of the students with the peer mentoring; 4) supporting efforts to create learning environments that promote student success. These arguments served as support for the design of the IMaR^2Fo Model (Figure 1).

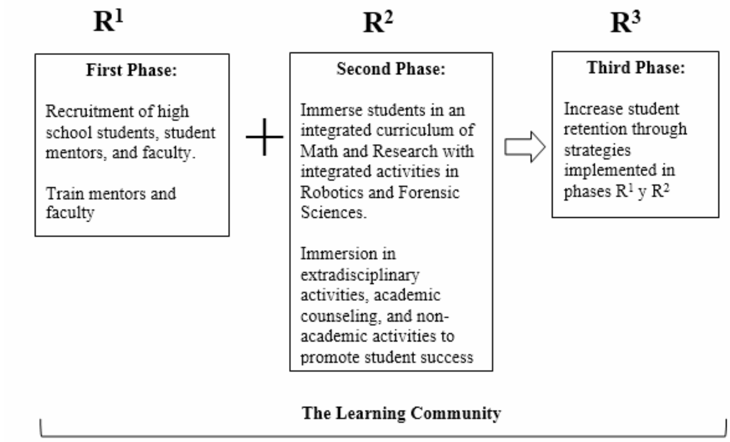

Figure 1. IMaR2Fo ModelR^3 Recruitment, Readiness, and Retention

2.4 Phases of the IMaR2Fo Model

R^1 Recruitment. Consisted of recruiting a multidisciplinary faculty in the areas of Mathematics, Engineering and Forensic Sciences and Research that was trained in the integration of teaching strategies applied to STEM using *a Train the Trainer* format, as these faculty will in turn, train other faculty members. Undergraduate students enrolled in STEM programs were recruited as peer mentors and received training in effective communication, leadership, and mentoring. High school students interested in STEM careers were recruited to participate in the HS-UBP program.

R^2 Readiness. It is an integral formation that consisted of curricular and extracurricular aspects of high school students.

R^3 Retention. Consisted of increasing the number of freshmen who selected a STEM career.

2.5 Description of the First Phase

The recruitment phase consisted of three (3) components: a) Faculty: Faculty representations were in the areas of mathematics, engineering, research, and forensic science. They were trained during a semester in teaching strategies. Professional development was facilitated once a week face-to-face workshops during an academic semester; b) High school students: Thirty (30) students interested in STEM careers were recruited and enrolled in a math course and a research course integrating robotics and forensic science activities and c) Peer Mentors: Undergraduate students were identified by the project managers and trained through 40 hours of workshops related to mentoring and mathematics applied to robotics. The process of the first phase is shown in Figure 2.

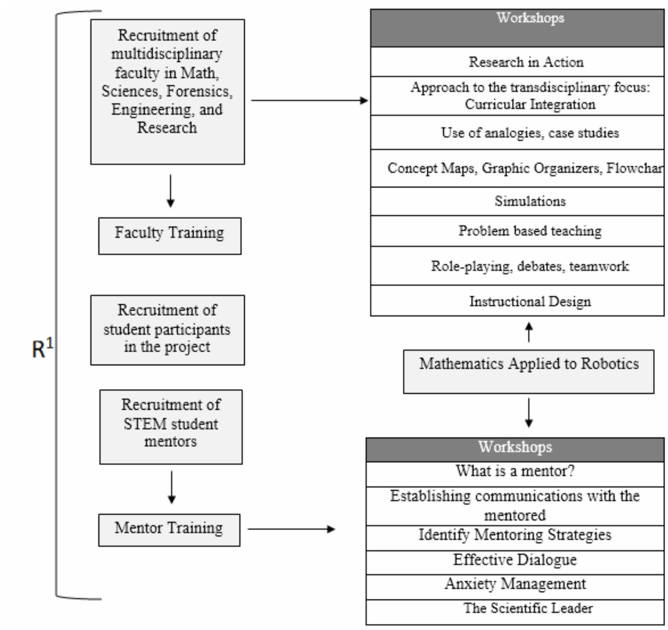

Figure 2. R^1: Recruitment and Training

2.6 Description of the Second Phase

In the readiness phase (Figure 3), an interdisciplinary team was setup among faculty from mathematics, engineering, research, and forensic sciences disciplines. This team implemented the previously developed curricular integration activities considering the common areas and skills in the contents of the courses. The high school students took a math and a research course, which were complemented with curricular integration activities in the areas of robotics and forensic sciences. The educational process integrated both the students and their peer mentors. Meanwhile the extracurricular training included academic counseling, non-academic activities, and parent support, in order to fully immerse high school students in the STEM learning community. In effect, a learning community for this project was understood as a set of academic and non-academic activities aimed at achieving the educational transformation of the STEM student in the institution in an integral way.

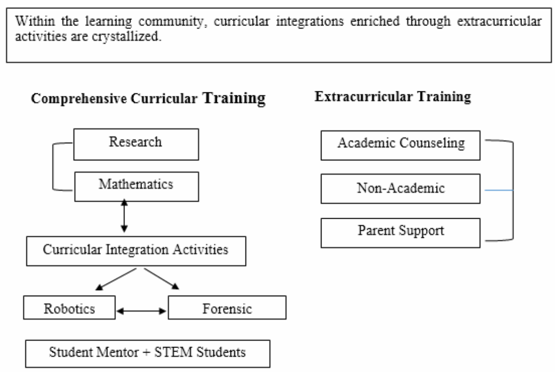

Figure 3. R^2: Readiness (Training). An integral formation consists of curricular and extracurricular aspects.

2.7 Description of the Third Phase

The retention phase was the outcome of the recruitment and training phases. This phase consisted of increasing the number of students in STEM careers (Figure 4). In addition, the recruitment and training of a multidisciplinary faculty from the disciplines of Mathematics, Engineering, Forensic Sciences and Research contributed to the integration of different points of view, enrichment and relevance of STEM students' learning. The capacity-building of faculty exerted a chain reaction in which STEM students were impacted more than once by the educational strategies. Therefore, it is presumed that the "Train the Trainer" strategy, which directly and indirectly affected the learning process impacted the STEM retention phase. Another factor impacting the retention of students was the comprehensive training received through the HS-UBP program, which included curricular and extracurricular aspects. This project provided a collaborative support system of several levels that interacted with a defined purpose of STEM retention. Observations and evaluations were added to the process to comprehensively assess students' progress in STEM careers.

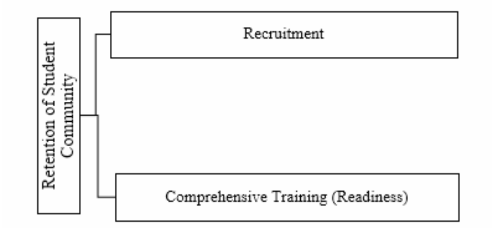

Figure 4. R^3 Retention. Retention consists of increasing the number of students in STEM career.

3. Strengths of the Model

1. The IMaR^2Fo Model to be implemented every year will be adjusted considering the data obtained in the preceding cycles. The adjustment will allow addressing the obstacles encountered in the process to achieve an optimal result of the project. Based on action research, possible problematic situations will be identified that will be addressed as they emerge in the development of the project. This aspect of constant reflection and formative evaluation strengthens the internal validity in the implementation of the two initial phases, recruitment and training.
2. Working in interdisciplinary teams enriches the academic contribution of each faculty who teach the dual-enrollment courses because they work within each discipline and share the same work goal (Torres, 1994). Modeling teamwork encourages other faculty to use this strategy in their classroom.
3. The contextualization of mathematics courses using real-life contexts allows learners to interact with their environment, an aspect that serves as a motivation in the teaching of this discipline. In addition, it allows learning issues to be addressed from different perspectives within the learning community.
4. *Train the Trainer* is a good strategy for the development of the faculty as it broadens the knowledge that each specialist has about teaching strategies in other areas, and it provides an exchange of knowledge in common and non-common areas to achieve optimal teaching strategies.

5. Peer-mentoring improves STEM knowledge in undergraduate students by helping their peers and in turn increases their self-confidence.
6. The extracurricular training provides a glimpse at the daily tasks related to the educational process within the learning community, which cannot be completely isolated from the academic performance of the STEM student.

In summary, as described above, UNE R^3-STEM provides a multi-level collaborative support system that begins in the recruitment and training phrases and continues until students' progress in STEM careers.

4. Evaluation of the IMaR2Fo Model

The model was evaluated during the first year of the project to determine its operating capacity. Results for the recruitment phase (R^1) of the model were evaluated during the first year of the project, specifically for faculty recruitment and development. The evaluation objectives were to: 1) evaluate the development of the HS-UBP, and 2) evaluate the FCDP. The results and conclusions of each objective are described below.

Objective 1. Establish a HS-UBP to increase recruitment of disadvantaged Hispanic HS students and their readiness for math and engineering.

The goal was to recruit 30 high school students from public schools in the institution's service area. The recruitment criteria to select the students were: entering in their senior year of high school, interested in STEM careers offered at the institution, and having a GPA of >2.0. During the recruitment phase, the project was presented at six high schools in our service area, impacting more than 200 students, of which 70 applied to participate in the project and 36 were admitted of which 56 % percent of the participants were female. Recruitment of faculty from education, mathematics, engineering, research, and forensic sciences included seven professors, 2 full-time and 5 part-time. However, a total of 30 professors participated in the workshops offered by the FCDP as the invitation was extended to all faculty at the institution. As such, faculty from the following disciplines participated: Social work, Psychology, Engineering, Mathematics, Microbiology, and Physics, Library sciences, English and Forensic sciences. In addition, five undergraduate students were recruited to serve as peer-mentors and tutors of the high school students. The recruitment criteria for the undergraduate students were to be enrolled in a STEM program, being in their sophomore year, having a GPA of $\geq$ 3.20, being recommended by faculty, and demonstrated interest in serving as a peer mentor.

Objective 2. Establish an FCDP to increase student retention by improving learning outcomes in math and engineering.

Bransford, Brown, & Cocking (2000) indicate that a change in the traditional paradigm of instruction (i.e., focused on the teacher or faculty member) to a student-centered approach promotes experiences that actively involve students in the learning process. To this extent, faculty were trained in holistic and innovative strategies necessary to address the needs of the student population by supporting their learning process and engagement. The topics of the workshops offered were Action Research, Extra-disciplinary Approaches/Curricular Integration, Graphic Organizers/Flowcharts, Case Studies, Concept Maps, Simulations, Problem-based Learning, Role Play/Debates and Cooperative Work. The selected topics were consistent with those discussed by Marzano, Pickering, & Pollock (2001) and others (Handelsman et al, (2004); National Council of Research (2012). The workshops were offered on a weekly basis for a total of 40 contact hours. All workshops were submitted and approved for continuing education credits. To evaluate the learning outcomes of the workshops, participants completed a pre- and post-test. It is important to note that the instruments administered collected both quantitative and qualitative data. Different assessment strategies were used during the workshops, such as a focused list, timelines, dialectic notes, checklists, and traditional multiple-choice tests were applied. In this way, the participating faculty received training in both teaching and assessment strategies without the need for additional contact hours. In addition, faculty satisfaction for each workshop was evaluated. The results are described below. To analyze the data, descriptive statistics were applied using the Intellectus Statistics program (2018). In the pre-tests, the initial faculty performance varied between 62% and 85%, while in the post-tests the performance average increased between 88% and 97%. Results (Figure 5) showed that the faculty had previous knowledge of strategies linked to cooperative work, conceptual maps, simulations, flow charts and case studies. However, they had less knowledge in Role play/debates, Problem-based learning, Action Research, and extra-disciplinary approaches /curricular integration. The results reflect the necessity to reinforce training in Action Research and subjects related to the extra-disciplinary approach and curricular integration, as they are not commonly applied in teaching.

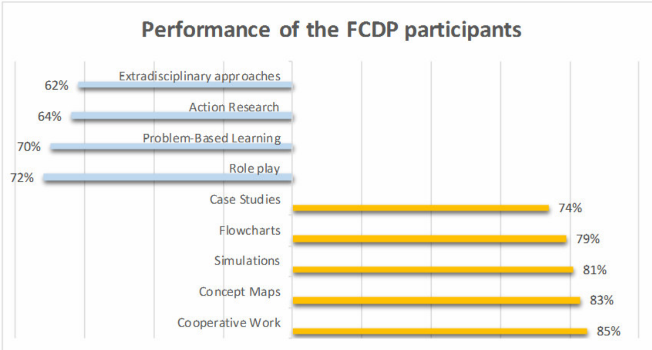

Figure 5. Performance of the FCDP participants

Overall, the application of the IMaR^{2}Fo model allowed for the simultaneous training of faculty from different disciplinary areas. For the initial evaluation, a comparison sheet was developed (Table 1) as a working document to identify the evaluation status of each strength. The six strengths of the model are shown in the first column and its status classified using the following criteria were: a) Evaluated; b) Evaluated but requires adjustments in the next cycles; c) Not Evaluated. The strengths evaluations will be embedded in an Action Research plan to continuously assess the operationalization of the model. To this extent, the implementation of the IMaR^{2}Fo model may change to some degree each year based on formative evaluation.

Strengths	**Criteria**		
	Evaluated in the first intervention.	Evaluated but requires adjustments in the subsequent cycles.	Not evaluated in the first intervention.
1. The IMaR2Fo model to be implemented every year will be adjusted in light of the data obtained in the preceding cycles using an Action Research approach. This adjustment will allow attending obstacles encountered in the process to achieve an optimal result of the project. Constant reflection and formative evaluation strengthen the internal validity of the model in the implementation of the two initial phases, recruitment and training.		**X**	

2. Work in interdisciplinary teams enriches the academic contribution of each teacher who teaches the courses because they work within each discipline and share the same work objective (Torres, 1994). Modeling teamwork encourages other teachers to expose themselves to this strategy.	**X**		
3. The contextualization of the teaching of mathematics in real-life scenarios allow learners to interact with their environment, an aspect that serves as a motivation in the teaching of this discipline. In addition, it allows addressing learning issues from different perspectives within the learning community.		**X**	
4. *Train the Trainer* is a good strategy from the point of view of the development of the faculty. In addition, it broadens the knowledge that each specialist has about teaching strategies in other areas. It is an exchange of knowledge in common and non-common areas working to achieve optimal teaching strategies.			**X**
5. Mentoring by undergraduate students contributes to the management of knowledge that is evident in each participant, by the greater degree of confidence and sense of reflection that the participants feel and observe in their mentor who is also a peer.			**X**
6. Extracurricular training allows exposure to daily tasks related to the educational process within the learning community, and that are not separate from the academic performance of the STEM student.			**X**

Table 1. Strengths of the IMaR2Fo Model

The initial evaluation of the IMaR2Fo strengths showed that: 1) the conceptual basis of the first strength allows for adjustments to be worked throughout the development of the project without departing from the essential aspects of Action Research; 2) a interdisciplinary team was achieved when the recruited professors joined the program and other faculty took the training voluntarily; 3) real-life scenarios were used to contextualize educational strategies in mathematics, research, forensic sciences, robotics and others and 4) the train the trainer strategy was partially achieved during the first year by pairing a senior educational researcher with a junior educational researcher to develop the IMaR^{2}Fo model and training modules, and when the junior educational researcher provided the workshops to the interdisciplinary faculty.

5. Conclusions

In summary, reflecting about the educational *praxis* is crucial in the operationalization of the IMaR^{2}Fo model. Currently in higher education, it is essential to become familiarized with different evidence-based teaching strategies that improve the development of competences such as scientific and quantitative reasoning, critical thinking, research and technology, among others. To this extent, there is a need of capacity building in educational strategies in STEM faculty. Usually this matter is treated very lightly or not treated with the required importance. This project attempts to correct this aspect by providing capacity-building opportunities to faculty from STEM disciplines and promoting faculty engagement in interdisciplinary educational *praxis*. Based on the aforementioned, faculty capacity building was an essential step to accomplish the goals of UNE R^3-STEM project, which were to increase the recruitment, readiness and retention of disadvantaged Hispanic high school students interested in pursuing careers STEM.

References

Ander-Egg, E. (2009). *El trabajo en equipo*. Madrid: Editorial Servilibro.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (2000). *How people learn: Brain, mind, experience, and school*. Washington D. C.: The National Academies Press.

An, B. P. (2013). The impact of dual enrollment of college degree attainment: Do Low-SES students benefit? *Educational Evaluation and Policy Analysis*, *35*(1) doi:10.31022F0162373712461933

Educosoft (Online Computer Software). (2018). https://www.educosoft.com/Home/US/es_u_default.aspx

Good, J., Colthorpe, K., Zimbardi, K., & Kafer, G. (2015). The roles of mentoring and motivation in student teaching assistant interactions and in improving experience in first-year biology laboratory classes. *Journal of College Science Teaching*, *44*(4), 88-98.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R... & Wood, W. B. (2004). Education. Scientific teaching. *Science*, *304*(5670), 521–522. doi: 10.1126/science.1096022

Intellectus Statistics (Online Computer Software). (2018). https://www.intellectusstatistics.com/

Keller J.M. (2010) *What is motivational design?. Motivational design for learning and performance*. Boston, MA: Springer,.

Klein J. T. (2008). Evaluation of interdisciplinary and transdisciplinary research: a literature review. *American Journal of Preventive Medicine*, 35 (2 Suppl), S116–S123. doi: 10.1016/j.amepre.2008.05.010

Marzano, R.J., Pickering, D.J., & Pollock, J.E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement*. Alexandria, VA: Association for Supervision and Curriculum Development. Association for Supervision and Curriculum Development.

Mechur, K. M., Calcagno J., C., Hughes, K. L., Wook, J. D., & Bailey, T. R. (2007). *The post-secondary achievement of participant in dual enrollment: An analysis of student outcomes in two states. National Research Center for Career and Technical Education*. Retrieved from https://files.eric.ed.gov/fulltext/ED498661.pdf

Morin, E. (2002). *Los siete saberes necesarios para la educación del futuro*. Madrid: Ediciones Nueva Visión.

National Research Council (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. Washington D. C.: The National Academies Press..

Nora, A., & Crisp, G. (2007). Mentoring students: Conceptualizing and validating the multi-dimensions of a support system. *Journal of College Student Retention: Research, Theory & Practice*, *9*(3), 337–356. doi: 10.2190/CS.9.3.e

Piaget, J. (1979). For an epistemology of interdisciplinary relations. In L. Apostel, & G. Seidman, A. (ed.). *College student retention: Formula for student success* (pp. 34-51). Westport, CT: Praeger Publishers.

Tinto V. (1993). *Leaving college: Rethinking the causes and cures of student attrition* (2nd ed). Chicago, IL: University of Chicago Press.

Torres, J. (1994). *Globalización e interdisciplinariedad: Currículo integrado*. Barcelona: Ediciones Morata, S.L.

Universidad del Este (2015). "*UNE R3-STEM: an institutional program to increase recruitment, readiness and retention of high-need High School students in STEM career pathways" Minority Science & Engineering Improvement Program Institutional Project 2015-2018*. Universidad del Este, SUAGM.