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Project method to build knowledge in expertise, communication, and critical thinking related to the environment

Método de proyectos para construir conocimiento en experticia, comunicación y pensamiento crítico, sobre el ambiente

构成有关环境的专业知识, 沟通和批判性思维方面项目的方法

Метод проектов для формирования знаний в области экспертизы, коммуникации и критического мышления об окружающей среде.

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Abstract

Objective. To observe the behavior of expertise, communication, and critical thinking with the project method. The research was carried out at Universidad Santo Tomás de Tunja with students from various undergraduate courses and with projects that are part of obtaining a civil engineering degree. Interviews, surveys, and observation grids were applied to teachers, instructors, and students. This was done with four undergraduate projects under the direction of the principal researcher, four teachers, four instructors, and ten students. The research began in 2012 and was documented from 2014 to 2018. Significant progress was observed in expertise, teamwork, critical thinking, and human competences. The results contribute to engineering education, although they may be useful for other professions.

Keywords: Life competences, Expertise, Project method, Experimental pedagogy, Critical thinking, and Experimental project.

Resumen

Objetivo. Observar el comportamiento de la experticia, la comunicación y el pensamiento crítico con el método de Proyectos. La investigación se llevó a cabo en la Universidad Santo Tomás de Tunja, con estudiantes de varios cursos de pregrado y con proyectos para optar al título de ingenieros civiles. Se aplicaron entrevistas, encuestas y rejillas de observación a docentes, monitores y estudiantes. Se hizo en cuatro proyectos de pregrado con la dirección del investigador principal, cuatro docentes, cuatro monitores y diez estudiantes. La investigación se inició en el año 2012 y se documentó desde el 2014 al 2018. Resultados y conclusiones. Se encontraron avances significativos en la experticia, el trabajo en equipo, el pensamiento crítico y en competencias humanas. Los resultados aportan a la educación en la ingeniería, aunque pueden ser útiles a otras profesiones.

Palabras clave: Competencias para la vida, Experticia, Método de proyectos, Pedagogía experimental, Pensamiento crítico y Proyecto experimental.

摘要

研究目的.　使用项目研究方法观察专业知识，沟通和批判性思维的行为。这项研究是在圣托马斯·德·通哈大学进行，研究主体为来自不同本科年级的学生以及在土木工程师资格项目学习的学生。我们采用了访谈，调查和观察网格的方法进行了四个本科研究项目，对主要研究人员领导，四名老师，四位班长和十个学生进行了调查研究。该研究始于2012年，其中对2014年至2018年的调研记录在案。结果和结论.　结果显示，在专业知识，团队合作，批判性思维和能力方面我们发现了重要的进步。这些结果有助于工程教育的发展，此外尽管对其他专业也可以有所帮助。

关键词：生活所需能力,专业知识, 项目方法,实验教学法,批判性思维和实验项目。

Аннотация

Цель. Рассмотреть поведение компетентности, коммуникации и критического мышления с помощью метода проектов. Исследование проводилось в Университете Санто Томас де Тунха, со студентами нескольких курсов бакалавриата и с проектами на титул инженеров-строителей. Интервью, опросы и наблюдательные списки применялись к учителям, воспитателям и ученикам. Это было сделано в рамках четырех проектов для студентов бакалавриата под руководством главного исследователя, четырех пре-

подавателей, четырех воспитателей и десяти студентов. Исследование было начато в 2012 году и документировалось с 2014 по 2018 год. Результаты и выводы. Значительные успехи были обнаружены в таких областях, как компетентность, командная работа, критическое мышление и гуманитарные навыки. Полученные результаты способствуют развитию инженерного образования, хотя они могут быть полезны и для других профессий.

Ключевые слова: Жизненные навыки, Экспертиза, Метод проектов, Экспериментальная педагогика, Критическое мышление и Экспериментальный проект.

Introduction

In the third decade of the 21st century, new challenges are faced in education that require the formation of visions of the future, with paradigms of equity and social justice in a world built in the physical, social, political and environmental aspects, given that the concentration of economic resources increasingly falls on a few people. Therefore, it is necessary to train and be trained to act in scenarios in which the vital and intellectual force can be put, to build not only professionals with instrumental competences but also human beings (Nussbaum, 2011). It is vital to contribute to the reorientation of the world to give priority to human development rather than economic growth, from the place where we are acting so that there is better coexistence, based on a greater redistribution of wealth, knowledge, education and resources (Sen, 2012; Perico-Granados, 2017).

In this regard, training is an act that includes several elements that collectively facilitate the making of human beings to promote them in all dimensions: physical, mental, emotional, and spiritual. This can in turn be enhanced with the participation of entertaining processes, such as comprehensive training (Gadamer, 2003). Training also involves the ability to observe its context, review the existing problems, analyze potential solutions, and seek to build a better future for that environment (Freire & Faundez, 2018). Comprehensive training has a policy that urges people to strengthen civil society so that it dominates the State and the State dominates the market (Pérez-Tapias, 2017). Thus, it is essential to promote training in human competences over other possibilities (Di Marco, 2020).

On the contrary, an essential part of training is environmental sustainability education. This is necessary in all professions and even more so in engineering, since it is directly related to exploiting materials, their transformation, use, and disposal in construction processes (Leonard, 2011). Now is the time, in 2020, to conserve and recover the environment in education before it is too late (Nussbaum, 2011). These professionals are also concerned with conserving the paramos and forests to store water that is carried through aqueducts. In addition, the treatment of wastewater is an essential part of the work, so when it is delivered to the effluent bodies, it is decontaminated (Leonard, 2011).

In this regard, when training professionals, especially engineers, holistic training is required, including disciplinary and humanistic aspects (Covey, 2013). In this way, it is necessary to train in expertise close to the profession, in building solid knowledge and communicating it, in teamwork, in promoting better human beings, and through reflection to encourage critical thinking as an essential component to grow and strengthen democracy (Aguirre, 2017). Communication is an important aspect in

building knowledge, as when used properly, it facilitates learning (Castellanos-Ramírez et al., 2020). These aspects should include projects and research related to the environment, which is getting increasingly degraded due to human activity (Perico-Granados, 2017b). It is a process that must contribute to reducing poverty and increasing freedom to learn about principles and values (Sen, 2012).

One way that contributes to the construction of knowledge through action, experimentation and reflection is with the project method proposed by John Dewey (Plate, 2011). This method allows learning through practice, materials, laboratories and their results, from the confrontation with other concepts, as developed by Kilpatrick (UNESCO, 2000). It is also successful when the project is close to the students and corresponds to their interests (Trilla et al., 2001).

The method, applied correctly and taking advantage of all its potentialities, trains in disciplinary competencies such as expertise. At the same time, it contributes to the formation of human beings who practice it in aspects such as solidarity, cooperation, autonomy, knowledge construction, critical thinking and teamwork (Zhou et al., 2012; Jamison et al., 2014). These are some of the aspects addressed in the present research, which was carried out in Tunja, at the Universidad Santo Tomás, in Civil Engineering, with professionals, young researchers, monitors and students.

Addressing this issue is essential due to the importance in designing and constructing safe work in the world, especially in Colombia (Perico-Granados & Arévalo-Algarra, 2019). Additionally, more training in human competences is required to overcome corruption and consumer society, aspects that burden the human development process. It is also important to reduce inequalities with a good education, which is one way to overcome poverty, given that the poor have fewer opportunities and fewer capacities to progress (Sen, 2012). Then, as a requirement, working appropriately to use the method so teachers gain all its potential must be considered. Teachers, in turn, will do the same with their students and have well-designed and built works created by excellent human beings (Granados et al., 2017).

It is a contemporary method, with educational processes in engineering, with different didactics and great potential in human formation. (García-Castro et al., 2018; Madrid-Hincapié, 2018). Then, it is expected that professionals, teachers and students can contribute with new actions to comprehensive training, which are being worked on in several European and Canadian universities (Jamison et al., 2014).

Materials, Methods, and Results

The research was documented between 2014 and 2018, as part of a project at Universidad Santo Tomás called "Training civil engineering teachers." Four projects were involved, led by the principal researcher. The following people served as researchers: an engineer and a student in "Variation of vegetation cover in Boyacá," conducted between 2014 and 2015; an engineer and two students in "Causes of floods in Tunja and proposed solutions" in 2015 and 2016; a biologist and seven students in "Study and revitalization of the Siscunsí paramo" in 2016 and 2017; and a biologist and two students in "Phytoremediation in previously untreated wastewater. Case study: Tierra Negra, Boyacá," in 2017 and 2018. Interviews, surveys, observation grids, and workshops were conducted to establish the progress in knowledge building in expertise, communication, and critical thinking related to the environment using the project method.

Weekly meetings were held to review project progress with the researchers as well as with students, instructors, and young researchers. The follow-up was carried out with reflections on actions taken and planning the following week as proposed in the educational action research study (Elliot, 2005). The instructors and researchers followed up with the students to review the learning objectives, as stated by other authors (Jamison et al., 2014). Periodic workshops, observation grids, interviews, and surveys were held. It was evaluated by applying instruments each semester to observe the processes and improve the new tasks with guidance from the principal researcher. The information obtained was triangulated and conclusions such as those described in the following sections were obtained. The projects were completed with what was planned in the educational research actions (Perico-Granados et al., 2015).

Building Expertise Related to the Profession

By applying the instruments and with monthly reflections, the growth in expertise and autonomy by the researchers and students was notable as the studies developed. Expertise is understood as a combination of practical experience, theory, and autonomy as the ability to make one's own decisions (Jamison et al., 2014). In this regard, in the vegetation cover project, the researcher and student decided to learn about the classification of areas, instruments used, measurements, correction methods, and project scope. Their expertise and autonomy gradually grew through field work, experiments, and in building concepts. Then, they were instructors in the Master of Aquatic Environment, which ended successfully.

The research project was based on Landsat images with an evaluation on land cover in Boyacá. The variation in area of forests, pastures, crops, buildings, erosion, and snow, among others, was assessed. All variables represent important elements in engineering. In this regard, the student analyzed the areas that create water storage in forests and paramos from which drinking water supply is obtained (Suárez, 2015; Perico-Granados et al., 2015). They built knowledge in their profession and independently, they each continue to study aspects of hydrology and the aquatic environment. They also continue to progress and guide classes and research as teachers in universities in these same subject areas.

In the second project, the engineer and the students were trained in expertise and autonomy based on decisions about visits, obtaining samples, and information. The students successfully presented on their practical experience compared with the theory of hydraulics and hydrology (Acevedo & Sánchez, 2016). They assessed the Jordán and La Vega rivers to highlight the obstacles that prevent water's normal flow or circulation, leading to floods. Thus, a process to model the floods in the city was conducted, and they built knowledge related to their profession and wrote an article for publication (Acevedo & Sánchez, 2016).

In the third project, the professional and the students worked in the field, took soil samples, characterized them in the laboratories, studied concepts and with their analysis were trained in expertise. The students took the initiative in the tours, made the diagnosis and projected with modeling the potential water reserves and were trained in autonomy (Puerto & García, 2016). They made a diagnosis of the vegetation cover in the Siscuncí páramo, in Sogamoso, to know the water retention capacity. The deterioration of this area was seen and with the modeling for the studied scenarios they proposed recovery actions (Perico-Granados et al., 2015).

The biologist and the students in the Tierranegra project were trained as experts with the work in the construction of the pool, obtaining of the buchons, taking and testing samples of these and of the water before and after the pool, their analysis in certified laboratories and confrontation with the concepts that guided the project, during one year, in the field work. The students were autonomous in their execution during this period, with the guidance of the principal investigator. These aspects were evidenced in the instruments applied and in the weekly reflection meetings. Their activity was immersed in the topic of the environmental component, which is a central part of the civil engineering profession (Araque et al., 2020).

Building Solid Knowledge and Communicating It

It was found in observations and voices of the actors, in all projects, that problem solving skills increased, as well as interpersonal skills. Motivation was present to conclude the research, disciplinary knowledge and human competencies were consistently built, such as communication, based on the orientation for this purpose (Perico-Granados et al., 2015). The oral expression capacity was substantially raised, the projects' sustentation was excellent, they developed excellent reports and published their results.

In this regard, in the vegetation cover project, the student also developed verbal fluency in the presentations and in the way they and the principal investigator dealt with each other (Suárez, 2015). The team was motivated during the project and both acquired solid knowledge in conservation and recovery of moorlands, aspects that they deepened in the master's degree in Engineering. The student acquired professional skills such as making real diagnoses, locating appropriate and relevant information, modeling scenarios and proposing government policies based on her research. It was found, both in the interviews and in the observations, that the construction of knowledge was done in a solid way and that the actors increased their capacities to communicate it. They advanced in confidence to expose their results in a partial way and the student sustained her public policy proposal. An excellent report was made and an article was published in the proceedings of the V International Engineering Congress (Perico-Granados et al., 2015). Presentations were held at local, national, and international events. In the call for young researchers, she ranked first among more than ten applicants.

In the Jordán and La Vega rivers project, the students progressed in interacting with their peers, the engineer, the principal researcher, and the laboratory workers. They learned to solve problems such as measuring areas and interpreting and using the land registry and hydrology and hydraulics models. They were motivated to complete nearly double the work initially proposed and increased the scope and results (Acevedo & Sánchez, 2016). Based on the project, today they know how to assess work on a specific route. They know how to process the information gathered and how to develop a flood model with different programs. They have the competences to make good presentations and produce research reports. They also built solid knowledge and demonstrated it in written documents as well as through oral support, with great success. Based on their knowledge, they proposed alternatives to solve the problem of flooding in Tunja (Acevedo & Sánchez, 2016). The project led to another interdisciplinary project to establish early warnings, which was registered under this name at Universidad Juan de Castellanos in Tunja.

In the Siscunsí project, the professional and the students had frequent interaction to build knowledge in the tours, laboratories and analysis of results, with the guidance

of the principal investigator. Problem solving skills increased in these processes and they proposed several scenarios to recover the páramo. Students learned how to take samples in the field, develop laboratory tests and contrast the results with theory. They used models such as HEC RAS and IBER, learned to structure projects, obtain relevant information, and present information properly. The degree of knowledge was highly evident because of their experiences at different work sites and the laboratory tests they prepared.

In the phytoremediation project, the biologist and the students regularly interacted with each other, the principal researcher, and the community so that they had first-hand information. The students planned the project, located the supply of the common water hyacinth, planted them, monitored them in the pool built especially for this purpose, took water samples, and then checked the samples in the laboratory and analyzed their results. In this way, they built solid knowledge, and less than a year after the project ended, they are working on similar projects in the department of Casanare. Similarly, the team developed communication competences in oral expression and in disseminating their results. They presented several papers in different spaces and published a general circulation article as well as one for a scientific journal (Araque et al., 2020). Similarly, they prepared a book chapter and submitted it for peer review.

Critical Thinking and Teamwork

Professionals, instructors, and students showed growth in building critical thinking and taking initiative. They saw themselves as the main protagonists, and they expressed that they gained teamwork skills. The projects encouraged actors to study areas they were interested in based on taking samples, analyzing laboratory tests, reviewing, and contrasting them with concepts and authors. The students took positions in regard to poorly designed or poorly constructed work and proposed new ways of completing them safely, complying with design and construction standards. This concept is similar to that suggested by authors such as Quintar (2008), Madrid-Hincapié (2018), and Perico-Granados and Arévalo-Algarra (2019) on taking a critical stance on surrounding reality.

In the vegetation cover project, the researcher and the student took a leading role. They took the initiative in searching for information and the project's development. The student strengthened critical thinking regarding climate change with the findings in the thawing of the Nevado del Cocuy, the increased erosion, and the loss of forests by more than 50%. She took the initiative to propose government policy processes to revive these areas with draft municipal agreements to present them to councilors from the population centers. She also took the leading role in searching for information from the department of Boyacá, made decisions about areas of study, defined categories of areas to develop, analyzed results, and compared them with other studies (Suárez, 2015).

We listened to the voices of the actors and saw in the projects, the action of subjects to build knowledge, the increase of solidarity and cooperation. The student played the role of apprentice subject, she was formed in the discipline of engineering with her findings, analysis of results and conclusions. The proposals she made are oriented to develop reforestation processes, motivated by tax exemptions (Suárez, 2015). The project was permanently evaluated with successful and the data obtained were confronted with the theories studied.

In the flooding project in Tunja, the students took initiative through visits along the rivers and by collecting information from companies. Their critical thinking was strengthened by the State's negligence due to the lack of initiative in early warning processes. This put the city of Tunja at high risk with a potential avalanche similar to Salgar in Antioquia, Mocoa in Putumayo, or La Chapa in Tasco (Perico-Granados & Arévalo-Algarra, 2019). They took the lead in the field visits, data collection, measurements, analysis of results, and drawing conclusions. The principal researcher guided the process through the weekly check-ins. The teacher proposed streamlining the objectives to avoid energy dispersal (Acevedo & Sánchez, 2016).

The students also developed capacities as subjects to learn as the process developed, by obtaining information and confirming it in the laboratory. By interacting during the project, they built knowledge from different tasks, and the camaraderie was also excellent, demonstrating clear progress in teamwork. The presentations demonstrated that the students learned autonomously, as they presented results at the weekly evaluations. They also showed good teamwork and both offered valuable contributions with mid-term reports and progress on field tests and trials with continual evaluation, until the project successfully ended (Acevedo & Sánchez, 2016).

In the Siscunsí paramo project, the professional and the students regularly took initiative in the field work and in laboratory tests. They gained critical thinking with knowledge on the damage in the paramo, especially with reduced coverage from the vegetation layer. They proposed policies and actions to conserve and revitalize it in various settings. They played a continuous lead role in the ten trips to the paramo with a two-hour drive in vehicles and on foot throughout the day. There, they took samples, conducted laboratory tests, obtained data to set up the scenarios with different programs, analyzed results, and developed conclusions (Perico-Granados et al., 2015).

In the phytoremediation project, the students used readings suggested by the principal researcher, and together with the professional, they observed sites with water contamination due to sewage. This encouraged the development of critical thinking. They built knowledge throughout the process with practical work and theoretical concepts. In the same way, they developed teamwork with the activities they worked on together, such as building the swimming pool, which they did as a group. They took the samples from the water and the common water hyacinth and worked in the laboratories to analyze the results together. However, in some cases, they alternated between the two students because of their other academic responsibilities (Araque et al., 2020). In general, the students were proactive, and as subjects learning various methods for field work and laboratories, they built solid knowledge foundations. Teamwork was good; they completed tasks together and with others and divided the work to perform better. During the entire process, the progress in field tests, laboratory tests, and information searching for modeling was continuously evaluated.

Better Human Beings

In all the projects, the actors consolidated human competencies such as solidarity, cooperation, teamwork, autonomy and critical thinking, among other elements that contributed to their integral growth. Likewise, the method was observed to reduce student desertion and academic mortality, based on the development of a taste for the profession, enhanced by field experimentation and laboratory tests. In the students who participated during the execution of the projects, these indicators were zero and learning increased with the description and construction of the problem. The projects

were successfully concluded and the actors observed the harmful processes of deforestation, the decrease of snow cover, the increase of eroded areas and urbanized areas, aspects that increase environmental problems. They grew in the disciplinary part and as human beings.

Likewise, in all the projects the students solved the problems that were presented to them in the process, worked as a team, with autonomy, solidarity, cooperation, responsibility, perseverance, presented excellent results, developed permanent interaction among themselves, with laboratorians, monitors, the professor and the principal investigator. They were creative in the search for information and in the activities for the creation of future scenarios and learned about sustainable development. They were trained as lecturers, wrote articles for dissemination, grew in knowledge of the profession and in integral formation.

Discussion

The expertise that was developed in the four projects was visible in the students' presentations, reports, and their support for the final projects. Progress was seen in the practical aspect, in the samples that they themselves took in the field, and in seeking concepts to defend their conclusions. The projects were aimed at conserving and revitalizing the paramo environment, watershed, regional deterioration, and essential aspects for water retention, which was then provided through aqueducts, a fundamental task carried out through engineering. In this regard, with the project method, given that they had practical experience and with the teacher's guidance, content can be seen that corroborates through experimentation that students consolidate their knowledge building and gain expertise (Kolmos et al., 2013).

In addition, as autonomous people and as professionals, both researchers and students experienced continual growth. They all continue to work on activities in the same field, in engineering as well as in teaching and research. Three of the researchers are continuing with postgraduate studies. With this work, they hope to make additional contributions to the environmental sphere. In this sense, with the project method, based on the processes of experimentation and leadership of those who participate in it, they are empowered and motivated to the extent that the knowledge they gain impacts them for a long time and can continue to affect their work (Jamison et al., 2014).

All the participants learned to use the tools, which were used on the samples, and the laboratory instruments to verify findings. They learned to solve different kinds of problems to complete their specific learning objectives. They did so under the guidance of instructors and based on reflection to familiarize themselves with the procedures. In this regard, a characteristic of this method is that it motivates and trains students to solve problems in their environment and in everyday life (Perico-Granados, et al., 2017).

In all the projects, disciplinary and human competences were gained, which were evident as they were completed and as they developed skills to communicate them orally. They empowered themselves through practical experience and with the security that it generated; they presented at different events, with national and international presentations, supporting their projects in an organized and distinctive manner. Proposals and presentations were made on public policies to reassess the conservation of forests and paramos. In this sense, with the fundamentals offered by the method and its ap-

propriate application, it promotes empowerment of knowledge that allows the actors to take ownership of the topics to present them confidently (Kolmos et al., 2013).

In addition, the progress in preparing tests and reports was important, given the preparation that was required, with the proposed guidance (Perico-Granados et al., 2015). In all of them, mid-term reports and a final report were submitted for each project. Articles were also written, of which four were published and one is pending. In these articles, specific actions are proposed to conserve forests, paramos, and ecosystems that are necessary for the future of human beings. In this regard, the motivation generated by this method leads to growth in many aspects, including those related to the profession and among the actors' relationships with each other. These aspects promote research among students and the dissemination of their results (Kolmos, 2015).

The researchers and students built in-depth knowledge in their specific research areas, given their motivation, commitment, dedication, and interest obtained by the method. Two researchers continue to work on the same issues and have submitted proposals in their municipalities to develop reforestation incentives based on tax relief. From these studies, other studies have emerged that are in progress to revitalize the paramos and provide early warnings to reduce the risks of floods and mass erosion. In this sense, with the learning that came as a result of the projects, researchers and students continue to conduct research and more topics arise, continuing along the same line (Hernández et al., 2015).

With these actions, the researchers and students in particular learned critical thinking and teamwork skills. With the students' analysis of works in the environment, during their complete process, up to comparing their results with theories, they took a position on poorly designed or constructed works or their absence due to State negligence, particularly in forests protection and paramos conservation. As a result, they suggested alternatives and proposed government policies that they promoted with different authorities. In this sense, critical thinking leads to facing the reality and seeing different options that allow for redirection to build a better world with affections and affinities (Quintar, 2008; Madrid-Hincapié, 2018; Perico-Granados & Arévalo-Algarra, 2019).

In addition, advances in solidarity, cooperation, and collaboration strengthened teamwork. These aspects were solidified with the progression and actions for each project in addition to how the activities were divided for more effective results. They took turns at different times, especially when the progression and actions took a long time. In this regard, because of the circumstances of the work done with a positive learning design, the students interacted collaboratively and displayed effective teamwork (Zhou et al., 2012).

Similarly, the project actors became better human beings based on the different competences they acquired and their comprehensive training. In addition, student dropouts and academic mortality decreased, and the students learned by studying and constructing the problem. They interacted more with each other and the members of the communities to promote actions aimed at protecting the environment. They acted responsibly, persevered, were creative, and grew in aspects that allowed them to develop as people. In this sense, with the characteristics of this method, the actors acquired competences that comprehensively promote the improvement of human beings (Dahl et al., 2016).

Conclusions

The project participants acquired specialized knowledge thanks to advances in practical experience and integrated theory on environmental issues, oriented to engineering. They grew in autonomy, in the use of sampling and laboratory tools, in professional knowledge, in research and problem-solving skills, and several of them, through their work as monitors, are now successful teachers.

The actors built disciplinary and human competences, which generated the necessary confidence for them to communicate results orally at national and international events and reports and articles for dissemination and publication in indexed journals. They made public policy proposals to conserve and revitalize forests and paramos.

From the study, reforestation and recovery proposals with tax relief incentives emerged based on the students' growth in critical thinking. They also resulted in new research on early warnings that can reduce risks of mass erosion.

The students improved their ability to work as a team, based on solidarity and cooperative work throughout their projects, both in the field and in laboratories. With the increased comprehensive training that was developed, the researchers grew as human beings.

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