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Experience, reflection and mediation in the construction of knowledge

La experiencia, la reflexión y la mediación en la construcción de conocimientos

知识建构中的经验、反思和调解

Опыт, рефлексия и посредничество в конструировании знаний

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Abstract

Objective: To determine the contributions of teacher experience, reflection and mediation to the project method. Methodology: article based on research conducted at the Pedagogical and Technological University of Colombia, UPTC from 2010 to 2017 and corresponding to the following research project registered at the same university: The training of civil engineering teachers based on the study of nine variables. It was carried out with seven research projects: four with engineering graduates, three with engineering undergraduates, and twenty introductory engineering projects. The method used was educational action research, with meetings held on a weekly basis in almost all of the projects and at longer intervals in others. The incidence of the variables in the method was verified with teachers, monitors, young researchers and students in the Civil Engineering programme at Santo Tomás University. Conclusions: it was concluded that experience contributes to reflection and reflection to the construction of knowledge and paradigm shifts

Keywords: educational environments, paradigm shift, exemplariness, experience, reflection.

Resumen

Objetivo: Establecer los aportes de la experiencia, la reflexión y la mediación del maestro al método de proyectos. Metodología: artículo con base en una investigación en la Universidad Pedagógica y Tecnológica de Colombia, UPTC, ejecutada durante los años 2010 al 2017 y obedece al proyecto de investigación inscrito en la misma universidad: La formación de los docentes de ingeniería civil con nueve variables trabajadas. Se hizo con siete proyectos de investigación: cuatro con ingenieros graduados, tres con estudiantes para graduarse como ingenieros y veinte proyectos de introducción a la ingeniería. Se hizo con investigación acción educativa, con reuniones semanales en casi todos ellos y en otros más distanciadas en el tiempo. Se verificó la incidencia de las variables en el método con docentes, monitores, jóvenes investigadores y estudiantes del programa de Ingeniería Civil de la universidad Santo Tomás. Conclusiones: se concluyó que las experiencias contribuyen en la reflexión y ésta a la construcción de conocimientos y al cambio de paradigmas

Palabras clave: Ambientes educacionales, Cambio de paradigmas, Ejemplaridad, Experiencia, Reflexión.

摘要

目的：确立教师的经验、反思和调解对项目方法的贡献。方法论：本文基于2010年至2017年在哥伦比亚教育与技术大学（UPTC）进行的一项调查，这项调查隶属该大学的一个的研究项目：分析9个变量在培训土木工程教师起到的作用。该项目由七个调查子项目组成，其中四个与已经完成本科学业的工程师相关，三个与即将完成本科学业成为工程师的学生相关，二十个与刚开始工程学本科的学生相关。我们对其教育行为进行研究，以现场形式或远程形式与所有项目进行每周例会研究验证了在与圣托马斯大学土木工程专业的老师，班长，年轻研究人员和学生相关的方法的变量关联。结论：研究得出，经验有助于反思，反思有助于知识的建构和模式的转变。

关键词：教育环境，模式转变，典范，经验，反思。

Аннотация

Цель: Установить вклад опыта, рефлексии и посредничества учителя в метод проектов. Методология: статья основана на исследовании в Педагогическом и технологическом университете Колумбии, UPTC, выполненном в период с 2010 по 2017 годы, и подчиняется исследовательскому проекту, зачисленному в тот же университет: формирование преподавателей гражданского строительства с девятью рабочими переменными. Это было сделано с помощью семи исследовательских проектов: четырех с выпускниками-инженерами, трех со студентами, которые должны стать инженерами, и двадцати проектов по введению в инженерное дело. Это было сделано с помощью исследования образовательного действия, с еженедельными встречами почти во всех из них и в других, более отдаленных по времени. Встречаемость переменных в методе была проверена с преподавателями, наблюдателями, молодыми исследователями и студентами программы гражданского строительства Университета Санто Томас. Выводы: был сделан вывод, что опыт способствует рефлексии, а это способствует построению знаний и изменению парадигм.

Ключевые слова: Образовательная среда, смена парадигмы, образец, опыт, размышление.

Introduction

At the beginning of the 21st century, humankind continued to evolve positively in many spheres, for example through improvements in communication technologies and advances in technological and transport means. However, some disciplines such as education have stagnated, especially in the areas of teaching, the practical application of principles and values and, in general, humanistic education (De Zubiría, 2012). For Nusbaum (2020) it is time for an in-depth examination of the formation of human beings from all perspectives, with greater emphasis on human competences. Likewise, Sen (2009) claims that poverty and hunger are due more to the unequal distribution of food, wealth and education than to food scarcity. According to Di Marco (2020), it is essential to build knowledge and human skills before any profession.

On the other hand, indicators show that climate change is worsening, with more floods, landslides, forest fires and hurricanes, aspects that further exacerbate inequalities since they normally have a greater impact on the most vulnerable (Leonard, 2015). These elements pose new challenges for students and teachers in different areas of knowledge, especially engineers. Engineering is a profession of high content and social responsibility. Its purpose is to promote a more equitable, just and more humanitarian world at political, cultural, social and economic level (Perico-Granados & Arévalo, 2019[a]).

In this regard, new opportunities are appearing for the application of new methods to build knowledge, such as problem-oriented and project-based learning (POPBL), which can partially provide answers. This approach has several interesting features, but only some were covered in this study, notably that in this method learning is oriented by the participants, especially by students, monitors and researchers, the experience of the actors matters, the method is based on activities and contributes to exemplariness, and it promotes reflection, teacher mediation and the creation of learning environments for the construction of knowledge (Kolmos, 2017).

In this sense, the participants' experience in the process makes a key contribution to the construction of knowledge, since an infant that touches a flame and gets burned learns more about that property of fire than they would from a teacher's explanations about the properties of heat (Dewey, 2014). A person who collects bottles, plastics and garbage from the river on a washing day will surely not throw paper and garbage on the street (Leonard, 2015). Experience in the construction of knowledge also enables learning to be strengthened (Urrutia-Heinz, 2020).

The method is based on activities such as sample taking, laboratory tests, visits to works projects and library and database searches. It is one of the actions that motivates students, since they abandon a passive attitude in the process and become protagonists in the construction of knowledge. The project method also reinforces exemplariness because participants who develop project execution skills in a specific area can later apply those skills in another project even if this is in a different field (Edstrôm & Kolmos, 2014).

The method also uses reflection throughout the practical and theoretical process. In this regard, pedagogy must include reflection in educational processes, teaching those in education to think, an aspect that transcends the practice of teaching. Reflections were made during the project based on classroom activities, successes and errors and actions that need to be changed to improve them (Elliott, 2005). The aim was to promote experience to resolve contextual problems through readings and an analysis of results, through reflection to propose solutions, change said solutions whenever necessary, promote their execution and thereby enhance the construction of knowledge (Jerónimo-Arango & Yaniz, 2019). Reflection must be based on the observation of identified environmental problems and work that is not done properly, and the teachers must guide students to find the best solutions for everyone, at both social and political level (Freire & Faundez, 2014).

Similarly, the method favours the development of learning environments for the construction of knowledge and thus provide a greater stimulus to students through, for example, trips to construction sites, observation and intervention visits and the performance of laboratory tests. This objective is also achieved through teacher mediation for the construction of knowledge by bringing students closer to knowledge and promoting interaction with their peers (Jerónimo-Arango & Yaniz, 2019).

Thus, the construction of engineering knowledge must abandon the memorisation approach and prioritise reasoning skills, problem solving, creativity, innovation, understanding of causal relationships and risk analysis (De la Portilla et al., 2019). A good engineer is committed to making this world a better place to live, in all aspects, especially at physical, social, political and economic level (Perico-Granados & Arévalo, 2019). However, reflection, which is a core element of education to redefine all dimensions of what is human, with competences that must transcend those provided by natural sciences, can be used to promote a pedagogy for engineering (Aguirre, 2017).

Method

The study was developed as a research project at the Pedagogical and Technological University of Colombia and was carried out with senior researchers, young researchers, monitors and students from Santo Tomás University in Tunja between 2010 and 2018. The problem was constructed based on the method proposed by Perico et al. (2015a). In-depth interviews were carried out with teachers, monitors and students.

Observation grids were prepared for them and permanent workshops were organised, with educational action research, using the methodology proposed by Elliott (2005).

For the research, the main researcher worked with the following projects: "The project method in road geotechnics, a case study: ballast for the Belencito–Paz del Río railroad", with three co-researchers and four students. "Diagnosis and proposal of a phytoremediation solution for wastewater treatment, in the Tierra Negra sector", with three co-researchers and four students. "Education and ethics to combat corruption", with two co-researchers and six students. "Characterisation and seismic recurrence in the Nido de Bucaramanga area", with one co-researcher. "Incidents in working conditions in the classroom climate", with two co-researchers. "The North-Eastern Railway and the Briceño, Tunja, Sogamoso dual carriageway", with three co-researchers. Sixty undergraduate students also participated, with twenty "Introduction to Civil Engineering" projects. Feedback sessions were held over fifteen semesters with all the actors, divided into groups and by projects, and the results were triangulated to obtain the main results, which are described below:

In the geotechnics, phytoremediation, ethics and seismic activity projects, the researchers led the processes in visits to gather information, perform and analyse the laboratory tests. The conclusions were obtained with the guidance of the main researcher. They highlighted the importance of their experience, acquired through different actions, in the construction of knowledge (Perico-Granados et al., 2019b; Araque et al., 2020). In the working conditions projects, during the process the researchers guided the development of the research with the teacher's guidance (Antolínez & Rivera, 2014). They guided the project with the school teachers, students, governing bodies and parents in the different spaces, based on the construction of the problem, gathering of information, analysis of results and field activities with the different participants to construct knowledge (Perico-Granados et al., 2014a).

In the railway project, the researchers travelled the railway line from Bogotá to Sogamoso, approximately 190 kilometres, to gather data and figures and take photographs. They visited entities like INVIAS (National Roads Institute) to gather information and supervise field work. They reviewed, gathered and processed data from the company Solarte y Solarte and analysed the results with the teacher's guidance (Soriano & Puentes, 2015).

In the "Introduction to Engineering" projects, many students adopted the role of leaders, took the initiative and constructed the problem with their classmates, determine the state of the art, defined objectives, proposed theoretical references, considered a methodology and developed the project in accordance with the proposal presented by Perico-Granados et al. (2015a). The students were empowered by the process, albeit some more than others, and in general all the participants guided the construction of knowledge under the supervision of the main researcher (Miranda, 2016; Perico, 2017b). Experimentation and the researchers' experience in knowledge consolidation actions in the six projects mentioned previously and in the introduction to engineering projects were important (Miranda, 2016; Perico-Granados, 2017b).

Activities that led to the development of the projects were carried out in all the projects. In the first four projects, actions consisted of sampling, laboratory tests, analysis of results, surveys, interviews, workshops and the gathering of secondary information. These actions facilitated the execution of the projects (Perico-Granados, 2017; Araque et al., 2020). In the working conditions project, the researchers developed activities with the entire academic community, gathering information, applying observation

grids, performing analyses and preparing reports and presentations (Antolínez & Rivera, 2014). In the railway project, the researchers carried out activities on the railway routes, gathering information in different spaces and settings, analysing said data and testing the theory, as well as giving presentations at different events and presenting the final report (Soriano & Puentes , 2015). An interesting aspect for students was that they spent a lot of time working on different field and laboratory activities. They gathered information and went to the library to consult information. Overall, these activities encouraged them to learn more and acquire knowledge, and they were able to do this with their friends and colleagues (Miranda, 2016; Perico, 2017b).

In all the projects, greater progress was observed in the investigative processes with the project method when the participants had completed other processes in the same or in different disciplinary areas. This process allowed them to acquire skills, which they then put into practice in the projects covered in this research; this aspect is defined as "exemplariness" (Edstrôm & Kolmos, 2014; Perico-Granados, 2017b). In the seven projects, it was observed that all the researchers had done research before and had acquired skills that facilitated the development of such research (Araque et al., 2020). In the working conditions study, the researchers had conducted research in collaboration with different teachers. In the railway project, the students had worked on projects in "Economics for Engineers" with the same teacher. The skills developed in those projects allowed them to achieve excellent performance in the present study (Perico-Granados et al., 2016). Today, one of them is carrying out research using the project method applying the learning and skills acquired.

In the "Introduction to Engineering" projects, it was observed that the students who had previously participated as interns in projects improved their skills and performance in subsequent projects. Many even became monitors in different subjects in the Civil Engineering syllabus. Two of them later served as postgraduate monitors: J. Ángel Miranda Bitar (Specialization in projects) and Paula Suárez Alvarado (Masters in Hydro-Environmental Studies) (Perico-Granados, 2017b).

Reflection on the process of knowledge consolidation in research was excellent in all the projects. Both the main researcher and the co-researchers, the young researchers and the monitors guided the students with questions, when necessary, to promote reflection in the construction of knowledge and to propose alternatives whenever the processes and results were poorly executed. In the projects, some constructions such as buildings, bridges and dams, both those that were well executed and those that were poorly executed, were analysed and the necessary reflections made to propose alternatives in the case of the latter (Perico-Granados & Arévalo, 2019).

In this regard, in the geotechnical project the participants reflected on the search for new ballast materials for the railroad and in the phytoremediation projects on potential alternatives to replace chemicals in the treatment of sewage, with proposals for natural treatments. In the ethics project, reflection was essential to determine the actual level of corruption and to observe alternatives in the department of Boyacá. A paradigm shift was also observed in the working conditions project, from the initial reactive position vis-à-vis the government to contact through the reading of articles and books recommended in the process. Videos were also used for reflection, allowing them to analyse and change their position and then intervene pro-actively in their communities, obtaining resources for school buildings, among other activities (Perico-Granados et al., 2014a; Antolínez & Rivera, 2014).

The reflection process was valuable as it enabled the railroad project researchers to focus their project and analyse the information independently. They used critical thinking to study the information and develop alternative proposals to reduce accidents and pollution. The railway is now operational and the line is being used to transport materials such as cement and iron. Through excellent reflection, the members of the research team, with the teacher's mediation, were able to resolve conflicts through negotiation (Soriano & Puentes, 2015; Perico-Granados et al., 2016).

With the motivation of the activities, especially practicals, visits to works projects and laboratory analyses, the students were able to reflect on the development of the projects and successful constructions and errors in the design and execution of works. This reflection was enhanced when they came into contact with the theory and discovered the differences between what they observed in reality and the theoretical concepts established in articles and books. Reflection is an essential foundation for the solid construction of knowledge (Miranda, 2016; Perico, 2017b).

It was observed that the construction of learning environments in all the projects enhanced motivation in and deepened the construction of knowledge. In the geotechnical project, many laboratory tests were carried out, together with visits to the railway line, sampling and discussions for the analysis of results. In the phytoremediation project, a pool was built with elements to prevent infiltration and increase travel time, to divert the water and carry out treatment using aquatic plants (common water hyacinths) instead of chemicals. Laboratory tests were carried out on both heavy metals and biological elements and their results studied (Araque et al., 2020).

In the ethics projects, information was gathered from the entities concerned, discussions were held to analyse the situation and all the data gathered were analysed. In the Nido de Bucaramanga project, the work team discussed the results extensively until precise conclusions could be drawn (Perico-Martínez, 2016). In the working conditions project, the co-researchers created different learning environments through meetings with the community, students and teachers and interaction with municipal authorities: they created gardens at the school and at homes and built a new headquarters for the school, at their request, based on negotiations with the community, councillors and the mayor. Based on their readings, they set up new educational activities with other learning environments, with elements from the environment (Perico-Granados et al., 2014a; Antolínez & Rivera, 2014).

In the railroad project, the co-researchers constructed learning environments such as railroad visits and information gathering with guidance from the teacher to obtain the important data. This allowed them to learn about railways and their characteristics to develop the project and consolidated the knowledge with which they were able to formulate alternative proposals to those proposed by the road transport market (Soriano & Puentes, 2015; Perico-Granados et al., 2016). Likewise, through various activities carried out in different spaces and times to build learning environments, the first semester students enjoyed and learned on the visits to the works and asked for the reports and for the publications they issued. They did the same when taking field and laboratory samples (Miranda, 2016; Perico, 2017b).

The principal researcher was responsible for mediating between the different knowledge areas and the co-researchers, young investigators, monitors and students. However, the most important aspect was the teacher's mediation to motivate, channel the energy of the participants, guide professionals and researchers appropriately, and

search for timely solutions to disputes in the different groups. It is also worth highlighting the experience and mediation of co-researchers, young researchers, monitors and laboratory workers with students.

In the first four projects, the teacher was present in the preparation of the preliminary projects, with the appropriate guidance and mediation to optimise the construction of knowledge. The teacher also participated in the execution of the projects, made suggestions on readings, reviewed progress, provided permanent motivation, analysed results and the precision of conclusions, with weekly meetings with the participants in each project (Perico-Granados et al., 2019b; Araque et al., 2020). In the working conditions project, mediation was carried out with readings and videos to which the co-researchers had access beforehand that facilitated paradigm shifts. In this way, they were able to identify new options and developed a transformational approach to addressing the real situation in school meetings and researchers' relationship with their environment, especially with parents and government officials (Perico-Granados et al., 2014a; Antolínez & Rivera, 2014).

In the railway project, the principal investigator also worked to mediate a conflict between two members of the work team. As a result of the problem in question, they sent letters to the dean to request the inclusion in the degree of the option to withdraw from the project. However, after rapprochement and the negotiation of agreements, with the teacher's mediation the students finally concentrated on their academic and research work. Mediation was also carried out with the students, the learning environments and knowledge. Thus, knowledge was constructed solidly and reflected in the presentations in different settings and in the preparation of the final report (Soriano & Puentes, 2015; Perico-Granados et al., 2016).

Through orientation and mediation, in the "Introduction to Engineering" course, readings, videos, tests, site visits and follow-up work on projects were proposed as appropriate. It was important to promote sampling, technical monitoring and the development of laboratory tests. Significant differences between the members of the groups were also identified on several occasions; mediation was carried out and appropriate solutions were found to enable the completion of the projects (Miranda, 2016; Perico, 2017b).

Results

In all the projects, important transformations were observed in the participants, researchers, students and the environment. The participants agreed to strengthen their commitment to research, social needs, ethics and the environment, and new knowledge was constructed. Environmental transformations were also achieved that are useful for the communities in which they intervened.

In this regard, in the first two projects significant advances were observed in the competences of the researchers, since they carried out the field, laboratory and conceptual construction processes. A commitment was undertaken to obtain effective materials for the railway and study the use of new natural elements for wastewater treatment (Perico-Granados et al., 2019b; Araque et al., 2020). In the ethics and Nido de Bucaramanga projects, in addition to enhancing investigative competences, important lines of research were identified in the review of corruption in Colombia and in relation to new elements on seismic activity in the country (Perico-Martínez, 2016).

In the classroom climate project, the transformation of the researchers was exceptional. Their reactive attitude of blaming and waiting for the government to solve problems made way for a proactive attitude: they became references for their communities and acted with a high degree of responsibility towards the environment and its context. They took the initiative for physical transformations through the construction of new classrooms, aspects that were achieved in less than two years. They promoted the use of novel teaching methods, such as agricultural farms and recreational activities. They went through a process of integration with the community and developed better knowledge-building actions with their students. To perform these activities, they obtained resources in collaboration with the municipality and bazaars and through participatory raffles with the community itself (Perico-Granados et al., 2014a; Antolínez & Rivera, 2014).

In the railway project, the transformation of the researchers was observed in aspects such as negotiated conflict resolution, which was achieved through teacher mediation. They prioritised their goals and responsibilities towards them and their peers over any potential disputes. Today one of the researchers continues to conduct research using the same methodology and the railway project is already operational. The researchers also became very responsible and committed individuals; previously in their careers they had obtained relatively low marks but now achieved excellent results in the project (Soriano & Puentes, 2015; Perico-Granados et al., 2016). The researchers constructed knowledge about road and rail transport and their results were presented in lectures and other events, and two articles were published in specialised journals. The disseminated knowledge is being used to propose other government policies on rail transport (Soriano & Puentes, 2015; Perico-Granados et al., 2016).

Transformations were observed in Introduction to Engineering students, especially with respect to their degree of self-confidence, at the end of the project, to continue studying Civil Engineering, thanks to the experience acquired in the method, their activities, the learning environments, the visits to the works projects, laboratory tests and sampling. Evidence of the students' ability to reflect was clear in the interviews and in the thesis. The interests of the monitors who participated in this study appeared during the initial process. Three of them appeared in competitions for young researchers and two were selected. They later developed and published their research. They revealed their transformation by acquiring skills as better human beings. The students feel more involved and independent, as reflected in their comments, and when combined with the other skills, academic mortality and drop-out rates diminish. It was observed that they increased their critical thinking, developed teamwork skills and, most notably, improved their oral expression and written communication skills. They were capable of resolving problems and significantly increased their expertise (Miranda, 2016; Perico, 2017b).

In the phytoremediation project it was difficult to obtain a plot to build the pool that was close enough to obtain readings on a daily basis. This aspect was resolved with the help of several co-researchers and the prototype was assembled. In the ethics project, many obstacles emerged when attempting to gather information in the departmental and national controllers' offices and in the attorney general's office. The information was only obtained after much insistence and many requests. The main difficulties encountered in the classroom climate project were the long distances the two researchers had to travel to attend the meetings with the teacher: about seven hours each from their workplace. They attended meetings every twenty days, with sessions of four to six hours each time to review and contribute to their processes during the

development of the project. Difficulties were also encountered with Internet access at home and work (both lived in rural areas and far from urban centres more than one hour away in each case). Then, every third day they travelled to the towns of Aguazul in Casanare and Muzo in western Boyacá to work night shifts. There was also an almost total lack of educational resources in the school meetings. For this reason, they set up agricultural farms to use them in their knowledge-building processes, as well as other recreational activities. Difficulties were also encountered with children from mining areas, who are difficult to deal with due to their aggressive behaviour. Thanks to the new skills acquired by the researchers, these children became better human beings, collaborators and participants, so much so that through them it was possible to involve their parents in meetings and integration and community work activities (Perico-Granados et al., 2014a; Antolínez & Rivera, 2014).

One difficulty in the railway project was the dispute between two of its members, which divided the work team for around two weeks. The teacher convened three meetings and with his mediation an agreement was reached to complete the project by separating work from interpersonal relationships. Subsequent meetings were attended by the teacher and despite some friction there were no more disputes. All commitments were fulfilled and work was completed according to schedule. Although the learning environments were excellent, difficulties were encountered due to the long distances that had to be travelled by rail and road to gather information. Motivation was fuelled by the researchers' interests in completing the long workdays (Soriano & Puentes, 2015).

Many people in the department made their living in the road transport sector and during the presentations they always expressed their opposition to the project. Even during the presentation, a jury openly expressed its strong objection to rail transport and insisted strongly on the uselessness of the project, an aspect that was overcome thanks to solid work and excellent presentations. Solid arguments and thought-out proposals were presented in all the discussions, for example the proposal to set up a mixed economy company with participation of the transporters. Eventually, the researchers came through the different presentations with flying colours. Since incomplete information was obtained from the different entities, data had to be triangulated and adjusted accordingly to ensure its coherent presentation (Soriano & Puentes, 2015; Perico-Granados et al., 2016).

A common difficulty in Introduction to Engineering were the different approaches used in teamwork. However, with the mediation of the teacher and the monitors, these interferences were overcome using the project method. Sometimes, field sampling was physically demanding for the students and more difficult when the group was only formed by women. For this reason, each work team was encouraged to always include one male student. When approaching the problem, students also tended to use the initial descriptors to develop the project. Thus, great insistence was placed on learning to construct the problem effectively and thus have greater certainty when setting objectives and implementing the methodology. Also, some students often asked what they had to evaluate and it was stressed that they had to evaluate the whole process and also the results. Similarly, some students were afraid to exercise the leading role afforded by the project method. In such cases, the teacher's motivation was needed to empower them until they acquired the necessary leadership skills to execute the project (Perico-Granados et al., 2015b; Miranda, 2016).

Difficulties also arose due to the limited tools for obtaining samples and performing the laboratory tests, and there was only one laboratory worker. Then, meetings were

requested with the dean and the syllabus committee, resulting in the approval and procurement of new tools and the designation of two new laboratory workers to set up a better work team with the monitors and one young researcher (Perico-Granados, 2017b).

Significant progress was achieved for each group of co-researchers, the principal researcher and all the participants. In the first four projects, the researchers constructed disciplinary knowledge and worked hard on human competences, ranging from collaboration, autonomy, cooperation and other skills to critical thinking based on reflection. Three of these projects were undergraduate and graduate degree assignments. The working conditions project enabled the students to obtain a master's degree in Pedagogy and the researchers, students, teachers and parents in the school meetings were able to develop their human skills (Antolínez & Rivera, 2014).

Special mention must be made of the human skills in dispute resolution acquired by the researchers in the railway project and significant progress was made in raising awareness in the academic community about the benefits of using the railway given the reduction in pollution and deaths. The attendees participated actively in the presentations and showed clear interest in the project. Despite certain infrastructural difficulties, the project is now operational (Soriano & Puentes, 2015).

Significant progress was made in the Introduction to Engineering projects, with the construction of knowledge in disciplinary aspects, especially in oral communication and, to a lesser extent, in written communication skills. Reflection to develop critical thinking and teamwork increased. New learning environments were created for the construction of knowledge. Human skills were consolidated and the school drop-out rate and academic mortality rate diminished. The students were empowered to play a more prominent role and participate actively in the project. The "Introduction to Civil Engineering" syllabus was modified and essentially structured based on the project method. They socialised with various teachers of subjects in which the project method had been developed, notably "Introduction to Engineering" and "Topography", in order to harmonise the study plans with the one proposed in this method. Likewise, all the evaluations were always carried out as evaluations of others and self-evaluations (Miranda, 2016; Perico-Granados, 2017b).

The researchers need more motivation to continue in the research processes with this method due to the greater dedication it requires. More resources should be included for new monitors, more laboratory workers and more teachers, all trained in the project method. The teachers also need more time to devote to the project method, which enables better construction of knowledge, through more reflection, and to create more and better learning environments.

The proposal is to continue with the on-going development of projects, if possible with the same team, in the different semesters. It is necessary to build a stronger project development culture, encompassing different aspects ranging from an excellent description of the problem to precise bibliographic references to ensure better project development. However, a more complete view of the co-evaluation process is still necessary.

Given the circumstances in which civil engineers must handle large amounts of money in their construction projects, corresponding to both the State and individuals, more in-depth research is necessary into the education of better human beings, especially in principles and values. More training is still necessary in oral communication, but especially to enhance writing skills and critical thinking and teach participants to be more

independent. It is expected that a similar project method based study plan will be implemented in the "Introduction to Engineering" subjects at this university, as well as in others in the city. An on-going training process for monitors is necessary to ensure continuity in the activities envisaged in the project-based method (Perico-Granados, 2017b).

Discussion and conclusions

It was observed that the students, monitors, young researchers and all the participants were able to independently lead the processes in the construction of the project, from the construction of the problem to the identification of the state of the art, the formulation of objectives and the definition of the methodology. They executed the projects with leadership and were motivated by experimental processes and by comparing their findings with theoretical concepts, an aspect that allowed them to cement their knowledge. Given the rather long research period, several students were motivated to become monitors. Four of them later became young researchers and two are now university professors. In this regard, Kolmos (2017) highlights that in the project method the participants guide the knowledge construction process, in contrast to the traditional method in which the teacher guides the process. Similarly, Edstrôm and Kolmos (2014) claim that experience in the process consolidates knowledge because learning is enhanced with the active involvement of the participants in the research than with the traditional method. Ruíz et al. (2010) indicate that experimentation is essential in engineering to promote learning and class attendance also improves.

Different activities were carried out in the projects, including the following: the construction of prototypes such as the swimming pool; laboratory tests; visits to gather information; meetings and discussions with academic communities and parents; gathering of data and figures from the entities involved and their selection, and the analysis of the results with friends and colleagues, which provided on-going motivation. In this regard, García-Castro et al. (2018) report that the activities carried out in the method are essential for students learning and motivation. Flores (2014) described the activities in constructivism learning that help in the process of knowledge construction. One way to acquire knowledge more easily is through actions, especially those specifically designed for this purpose (Moreno de la Rosa, 2011).

In the projects designed to allow students to obtain a master's degree or specialisation and even an undergraduate degree, the researchers already had prior experience, which allowed them to apply the skills acquired in those projects in their degree work. The same occurred in the Introduction to Engineering projects; these projects provided them with the skills to execute subsequent projects, an aspect that motivated them some of them to become monitors. Kolmos (2017) indicates that the skills developed in a previous project facilitate the execution of the next one even if the subject-matter is different; this aspect is defined as "exemplariness".

Reflection became more important due to its use in this method, in contrast to the traditional method that favours memorization. Thus, the students constructed knowledge on a solid basis, confirmed the benefits of well-executed projects and observed the problems caused by poorly executed ones, all based on reflection. This was a preliminary step for critical thinking. As a result, paradigm shifts were observed, for example the use of only chemicals like chlorine and aluminium sulfate in wastewater

treatment and the verification that natural methods can be used for this purpose. Similarly, reflection showed the participants that the responsibility for education goes beyond the Government and includes teachers through their hard work and proactivity. Changes were also observed in both researchers and students, who realised that rail traffic has less impact on environmental pollution and its use helps reduce fatalities.

In this regard, Edstrôm and Kolmos (2014) indicate that reflection is essential in the construction of disciplinary knowledge and in human skills training. In contrast, Quintar (2008) claims that reflection is the way in which human beings learn to correct their mistakes, based on critical thinking. In this sense, knowledge is founded and consolidated based on reflection on experiences, practices and theory (Shôn, 2013). A good teacher is a good researcher and this requires them to reflect on their practice as teachers (Ramón, 2013). To understand the reality and make meaningful contributions, it must be approached from a different perspective based on reflection to make better decisions (Zemelman, 2015). Reflection is also necessary to visualize the structure of principles and highlight the best options for all the persons involved in solving a problem (Covey, 2012; Perico-Granados et al., 2104b).

The project method promotes the continuous development of new learning environments. Different activities were carried out within the scope of this study, including sampling and laboratory tests, trips to railway lines and roads, construction of prototypes and new scenarios in the field to construct knowledge in the academic discipline and consolidate human competences and, in many cases, propose alternative solutions and organise debates to analyse the results. In this regard, de la Rosa (2011) indicates that actions allow people to construct knowledge, which is enhanced when they switch to different learning environments. When teachers invest time in creating new learning scenarios, students make more use of their time and improve their construction of knowledge (Kolmos, 2017).

The teacher's timely mediation in the method was essential for the proper construction of knowledge. This was achieved through collaboration between the main researcher and the co-researchers, monitors, young researchers, students and the different knowledge areas. Teacher mediation was also important for the continued motivation of the members and the resolution of conflicts that arose during teamwork in various projects. In this sense, Edstrôm and Kolmos (2014) and Perico-Granados et al. (2017c) report that timely teacher intervention is crucial to redirect projects, whenever necessary, but should be avoided when everything is working well. According to Hernández et al. (2018), the teacher will focus on the development of the projects to prevent these running out of steam and to guide their development when this is essential.

With the application of the project method, important transformations were observed in the researchers, with the construction of disciplinary knowledge, and exceptionally as human beings in social aspects and in their ethical commitment. Significant transformations were observed in the researchers' environment to their detriment, in the form of constructions now at the service of the community. It would have been hard to achieve these aspects of learning with traditional pedagogy. One noteworthy aspect of the projects was that the different participants were empowered and were able to use their newly-acquired leadership skill and autonomy to resolve problems that arose in the field and in the laboratory tests. Different theorists have examined in depth and confirmed the increase in knowledge construction but not the transformations achieved in participants and the environment (Edstrôm & Kolmos, 2014).

The project method generates motivation and arouses interest in research, encouraging students want to continue in learning processes, since it is based on experience, practice and activities designed and guided by the actors involved.

The method promotes reflection, which facilitates the construction of knowledge through the comparison of practical work with theory, which can become a habit and thus contribute to critical thinking. Reflection also promotes paradigm shifts in researchers and in their environment, as exemplified by the use of natural elements to decontaminate water and prioritising rail transport over the use of lorry transport, among other aspects. Reflection also avoids exclusively instrumental training.

One of the main characteristics of the project method is that it fosters the continuous creation of new learning environments in the form of, for example, sampling activities, laboratory tests, prototyping, visits and new scenarios to construct knowledge of the discipline and consolidate human skills.

The method encourages teacher mediation between the actors in the process, the learning environments and knowledge, and between the actors themselves in the event of conflicts arising due to greater interaction between them. The teacher provides permanent motivation.

The method is also noteworthy because it facilitates the achievement of transformations with the construction of knowledge in the subject area and in human skills, as well as in the environment, with constructions for community use, an aspect that is not achieved with the traditional method. The participants are empowered and exercise leadership, allowing them to resolve problems in the field and in the laboratory to complete their projects.

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