# Integrative-training projects as a strategy to develop professional skills in future engineers

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**Abstract**

*The results of an investigation developed at the National Technological Institute of Mexico / Tantoyuca campus with students of the 6th semester of petroleum engineering are presented, in which the role played by students in a collaborative learning environment that demands challenges is investigated. For the experimentation, the methodology "integrative-formative project" was applied in order to generate a new way for students to develop skills. The hypothesis that led the research was: Will this type of learning environment "integrative-formative project" achieve the incorporation of the student in a leading role in the process of building professional competencies? By participating in this project during the professional training process, the student learns to learn, applies knowledge to solve problems, develops research activities and has an interdisciplinary and metacognitive vision. It constituted experiential experiences in solving desirable aspects for companies and produced satisfactions in students and teachers*

**Keywords**: Integrative-formative project, Competences, Collaborative Active Learning, engineering design process

## 1. Introduction

Globalization processes currently demand professionals with the ability to solve problems, who make optimal decisions, creators of innovative solutions appropriate to the context. Currently, at the higher level, the aim is to develop new pedagogical strategies that allow the training of engineering professionals who join the productive sector with the competencies required by increasingly dynamic work and social environments. The new methodologies seek to promote the development of generic (soft) competencies requested by the labor market such as: learning to learn, organize and plan, analyze and synthesize, apply knowledge to practice.

To meet these demands, the National Technological Institute of Mexico(TecNM) has proposed a student-centered educational model, with multiple active-collaborative learning environments (Case Methods, Problem-Based Learning, Project-Based Learning, Project-Based Learning Integrators-Training and Technological Environments) aimed at the training of professionals as agents of change, who generate value for society by making informed decisions, enhancing the resources at their disposal and positively impacting their environment; likewise, it promotes, encourages and strengthens national and international development through research, innovation and entrepreneurship, social responsibility and the ability to generate information and useful technology for economic and social development.
The educational model of the TecNM considers the academic axis as a fundamental pillar, using strategies in multiple learning environments, among these environments, integrative-training projects are considered as the meaningful learning strategy to gradually bring the student closer to social reality and promote understanding of the problems in their environment.

The structure of the development of integrative-training projects is an impact pedagogical strategy, being important because it potentiates the development of competencies such as observation, planning, design and execution of

systematic actions that take into account a problem in the environment in which one works by providing possible solutions, where theoretical knowledge is applied and articulated in practice, using the knowledge acquired from the different subjects (basic, engineering and specialty) included in an academic program.

### 1.1 Research justification

The intention of this research is to propose a methodology that gives students the opportunity to build an active-collaborative learning process based on their own experiences that stimulate curiosity and develop skills (knowing-knowing how to be-knowing how to do). Offering the possibility to explore, manipulate, suggest hypotheses, make mistakes and recognize them, justify, argue.

The integrative-training projects are framed in criteria of curricular flexibility. They promote interdisciplinarity in the development of basic, generic and professional skills. It problematizes knowledge in a context of academic development and involves scientific-technological research and the engineering design process in the solution of social, economic and environmental problems; from innovation and engineering creativity through the University-Company relationship.

By participating in projects of this nature during their professional training, the student learns to learn, applies knowledge to solve problems, develops research activities and has an interdisciplinary vision. These projects constitute experiential experiences to develop specific and generic skills, the latter make up the desirable aspects for companies, such as ethical commitment, leadership, teamwork and the ability to communicate orally and in writing, among others.

Articulate theory and practice by linking students to a context of social and business interest; strategies that offer opportunities to students to relate and apply integrative knowledge in their professional experiences, corresponding to the area of disciplinary training, by addressing real engineering problems in context and transferring practical experiences to the classroom for study and analysis. Methodologies that strengthen the professional training process, through the development of skills, abilities and practical skills. In this sense, the knowledge acquired becomes significant, due to the experience experienced when facing the challenges requested by the real problems of engineering.

#### 1.1.1 **Background**

The need for a new learning model for the 21st century is mainly focused on three aspects: the competencies, the aptitudes necessary to function effectively, and the pedagogy that is required to stimulate these capacities. Likewise, the importance of personal competencies for the world of work, such as initiative, responsibility, risk-taking and creativity is highlighted; social skills, such as teamwork, networking, empathy, and compassion; and learning competencies, such as management, organization, metacognitive abilities, and the ability to turn difficulties into opportunities.

Given these demands, it is essential to offer methodological alternatives that allow students to take greater responsibility in their own learning process. The design and operation of real and significant projects that favor the construction and development of competencies, knowledge, skills and attitudes, to face the problems that life poses. Methodologies are integrated into the professional training process, as a trigger for the development of skills, abilities and practical skills. In this sense, the knowledge acquired becomes significant, due to the experience experienced when facing the challenges requested by the problems that provide solutions to social, economic, environmental problems, etc.

#### 1.1.2 Theoretical framework

The integrative-training projects are framed in criteria of curricular flexibility. They promote interdisciplinarity in the development of basic, generic and professional skills. They problematize knowledge in the context of the development of the academic program and involve scientific and technological engineering research in solving social, economic and environmental problems from innovation and engineering creativity through the University-Company relationship.

The intention of this research is to propose a system for the construction of professional competencies through a methodology that gives students the opportunity to build an active learning process based on their own experiences that stimulate interest, curiosity and develop competencies (knowing being, knowing how to do, knowing how to know and knowing how to live together). Offering the possibility of exploring, manipulating, suggesting hypotheses, making mistakes and recognizing them, rethinking if necessary and arguing.

#### Integrative Projects

Integrative projects are incorporated into education as a curricular strategy that allows generating a new way for students to develop competencies, which means that they must contemplate opportunities to learn to act in a comprehensive and not individualized way. Every project seeks to address problems in the context, and in that sense it is the most comprehensive strategy for the training and evaluation of competencies (Tobón S., 2010)

**Training projects**

Training projects are articulated sets of learning and assessment activities to analyze and solve context problems, seeking the development of skills in students. They are based on linked activities, collaborative work and evaluation with real products (Tobón, 2014). In every training project, the development of competencies is sought while working on these key aspects through the resolution of context problems, knowledge management and collaborative work.

The training projects are a general strategy to train and evaluate the competences in the students by solving pertinent problems of the context, by means of directing, planning, acting and communicating the activities carried out and the products achieved.

Training projects are part of socioformation and are within the knowledge society.Socioformation is an alternative educational approach aimed at forming citizens with a solid ethical life project, entrepreneurs, with collaborative work and knowledge management, focused on the identification, interpretation, argumentation and resolution of context problems with progressive levels of complexity, combining individual and team work, and carrying out a process of continuous improvement through metacognition (Tobón, 2013)

**Professional skills**

For the National Technological Institute of Mexico a competence is the integration and strategic application of knowledge, procedures and attitudes necessary for the solution of context problems, with a professional, ethical, efficient and pertinent performance in heterogeneous and changing work scenarios. The competences, from the socioformation, are integral actions to identify, interpret, argue and solve problems of the context with suitability, ethics and continuous improvement. They imply the articulation of knowledge such as knowing how to be, knowing how to do, knowing how to know and knowing how to live ((Tobón, 2013, 2014).

Competencies have the following key characteristics from socioformation (Tobón, 2013):

- They are performances or actions in the environment. They are not exclusively internal processes,
- They are based on knowledge management,
- They articulate different knowledge: knowing how to be, knowing how to do, knowing how to know and how to live together,
- They focus on solving problems of the context,
- They are based on strong values, such as responsibility, honesty, respect and fairness.
- They seek suitability, focusing on meeting pre-established or agreed-upon quality criteria in the context.

**Integrative-Formative Project**

An integrative-formative project is a didactic strategy that consists of carrying out a set of interconnected activities, with a beginning, a development and an end with the purpose of identifying, interpreting, arguing and solving a problem in the context, and thus contribute to to form one or more competencies of the graduate profile, taking into account the approach to a significant problem in the disciplinary-investigative, social, labor-professional context, etc. (López Rodríguez, 2012).

**The engineering design process**

The design didactic experiences in the training of engineering students should be oriented to the content, the development of mathematical thinking, the usual work of an engineering professional and the development of strategic thinking oriented towards the use of design. Engineering design is not a finished product but a methodology that relies on knowledge, inventiveness, creativity and awareness of the concept of urgency, to visualize a real problem, formulate it in technical terms, explore possible solutions, evaluate alternatives, propose one or more forms or ways of solution, evaluate the possible processes that need to be used and their corresponding results, select one of the best solutions based on a set of criteria, execute the necessary actions to carry out a particular proposal and evaluate the process and the results of each and every one of the actions, permanently making adjustments and corrections and issuing judgments and recommendations that are based on facts, preferably quantifiable.

2. **Methodology. Phases of the methodology of an Integrative-Training Project**

The development of this type of project requires "transiting-articulating" between different phases

1. Contextualization and/or Diagnosis of the problem to be solved
   • Approach and recognition of reality and / or identify the problem to be solved with the students,
   • Establish the scope (personal, work-professional, social, ecological-environmental, etc.),
   • Definition of the necessary research process and methods,
   • Linkage between the disciplines that contribute to solving the problem,
   • Visualization of the positive implications of its resolution in the current context,
   • Agree on the key actions of the project with the participation of the students.
   • Establish the collaborative work process of the project.
2. Rationale. Referential framework (theoretical, conceptual, contextual, legal)
   • Analysis of previous knowledge,
   • Brainstorming or mental maps to gather information about the problem posed,
   • Propose a case analysis that generates reflection, the search for information in previous experiences and thus mobilize later learning,
   • Analyze and understand the key concepts involved in the context problem,
   • Agree with the students the activities to appropriate the necessary knowledge and favor the resolution of the problem in context,
   • Understand and argue the problem with the knowledge addressed.
3. Planning
   • Diagnosis of the current situation,
   • Plan a process of business, social or community intervention, etc.
   • Carry out the work schedule (Gantt chart)
   • Design of the project by the students with the teacher's advice.
4. Execution
   • Development of the project planning by the students with the teacher's advice,
   • Make a diagnosis of the context where the problem is located,
   • Determine the context of application of the problem and the necessary knowledge,
   • Construction of the proposed model according to the type of project,
   • Find the relevant resources in the context to solve the problem,
   • Development and application of generic and specific competences to be trained
5. Evaluation
   • In this phase, the construction of knowledge is put into practice: knowing how to know-how to do-know how to be,
   • Solve the problem with a certain strategy,
   • Consider options in solving the problem,
   • Applies a value judgment in the labor-professional, social and investigative context,
   • The evaluation is carried out in three interdependent dimensions: self-evaluation-co-evaluation-hetero-evaluation
6. Socialization of the learning process and problem solving
   • Present the necessary evidence regarding the resolution of the problem, socializing the results of the application of the project,• Co-evaluate the evidence and achieve continuous improvement,
   • Share the products of the project with other students, the community, the directives of the educational institution, etc.

**3. Evidence of the substantive moments when implementing the methodology "integrative-formative project"**

**Phase I.** Contextualization and / or diagnosis of the problem to be solved

**General description of the identified problem**

Water security in Mexico in the future is compromised. The condition of poverty that excludes access to drinking water and sanitation services becomes a difficult state to overcome because it is associated with hunger and disease. The water must have adequate characteristics for human consumption, otherwise, it causes damage to health and especially

to infants. Faced with this problem and identified opportunity, the project is proposed to support CONAGUA in managing the comprehensive management of groundwater.

Exposure and identification of the problem, it is necessary that all those involved understand it, brainstorming is generated for a first approach and reflections on the phenomenon to be investigated and challenges to be solved. Students recognize relevant situations linked to related issues in their engineering training process and with the development of professional skills. Opportunities for discussion and feedback are created with the intention of proposing nuanced solutions. Figure 1 shows images of a look at the existing problems of drinking water supply at the local-regional-national-world level.

Fig. 1 Identification of the existing local-regional-national-global problem of drinking water supply.

**Objective**

Design, build and install a manual pump with a friendly technical innovation, to extract and purify water up to a depth "N". In order to manage the water security of the aquifers by zones and guarantee supply with the motto: "water is life ... there is life for everyone"

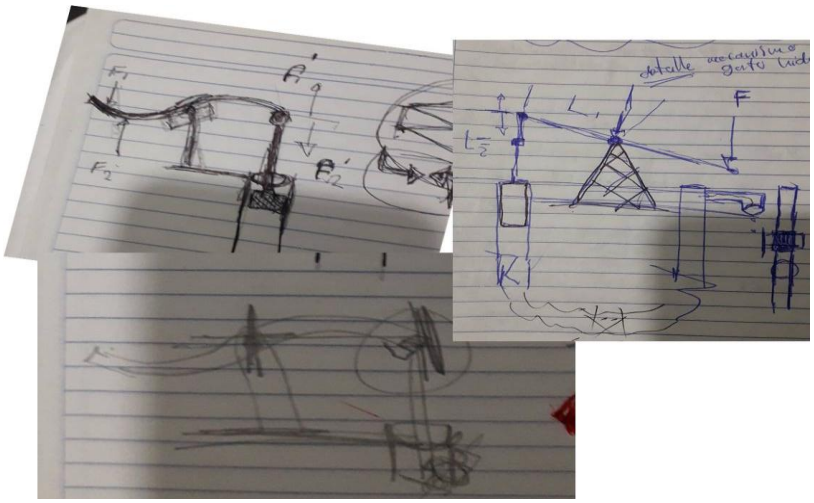

Figure 2. Student sketches second approach brainstorming, discussion and collaborative work.

The teacher presents proposals for students to select the one that suits them best and interests them. Motivation and enthusiasm are stimulated in the development of tasks, for example, pointing out the importance and impact of the project, sharing professional experiences, presenting information from previous research or projects, and asking challenging questions. . Opportunities for discussion and feedback are created with the intention of proposing solution perspectives. The teacher accompanies the team in the generation of ideas to ensure that the project has a clear direction and support. The figure 2 presents the first sketches as a result of the second approximation using the methodology brainstorming and debate on the proposed solution.

Phase II. Rationale.Referential framework (theoretical, contextual, legal) Addressing the phenomenon in research and knowledge analysis. Students collect information with the purpose of knowing the research phenomenon and deepening its fundamentals. In this phase, prior knowledge is articulated with those that are currently in process to be applied later, in this case they integrate the competencies of the subjects (fundamentals of research, sustainable development, fluid mechanics, research workshop, hydraulics, instrumentation, workshop II, formulation and evaluation of projects) The teacher constantly provides feedback with the intention that they focus on the object of study of the project. The brainstorming methodology is organized in a third approach to focus, base and contextualize the phenomenon under investigation, pose and rethink questions about necessary knowledge. Space where the student has the opportunity to discuss ideas and restate previous hypotheses. Figure 3 shows how the construction sketches of the manual pump have been refined and modified. It is this phase that begins with the engineering design process.

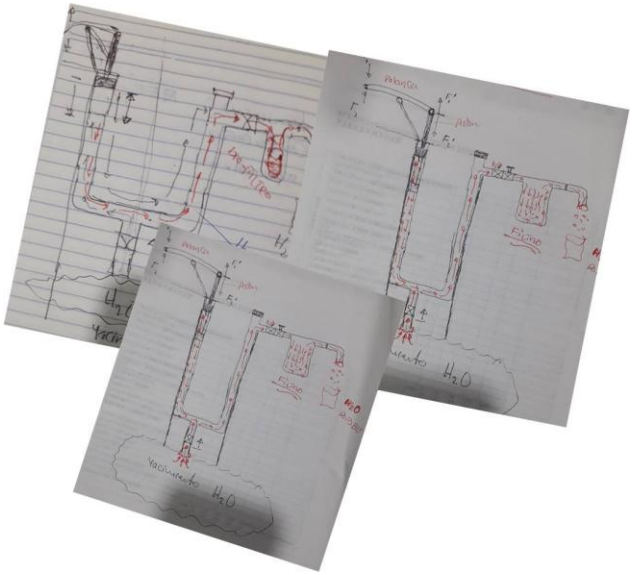

Fig. 3. Third approximation of the idea sketches of the hand pump.

The project has a social impact that will help meet the demand in areas where there is no vital liquid "water is life ... there is life for everyone." Water management is an issue that must be a priority for the nation and it must be understood that it is associated with environmental and economic sustainability and social stability. Access to drinking water and sanitation services makes it possible to satisfy basic needs and contributes decisively to human development, with multiplying effects on education, food and health.

**Phase III. Planning (definition of objectives and work plan)**

The students and the teacher establish the objectives of the project by making a diagnosis of the current situation, considering the necessary resources and times. Project management is developed using a Gantt chart to schedule the activities necessary to achieve the project objective in a timely manner. A representative work team of the group called Engineering Staff is organized to provide timely follow-up of the activities with the teacher's advice.

Results that are intended to be achieved with the development of the project:

**Cronograma de actividades (diagrama de Gantt)**

| Actividad | Feb. | Mar. | Abril | Mayo | Junio | Julio | Ago. | Sep. | Oct. | Nov. | Dic. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lluvia de ideas para abordar la problemática situada que representa un reto | → | | | | | | | | | | |
| Investigación previa | | → | | | | | | | | | |
| Concreción de ideas | | | → | | | | | | | | |
| Definición del problema | | | → | | | | | | | | |
| Recopilar información técnica relativa a la mecánica de los fluidos y bomba manuales | | | | → | | | | | | | |
| Seleccionar los accesorios del prototipo de la bomba manual | | | | | → | | | | | | |
| Elaborar el presupuesto | | | | | | → | | | | | |
| Diseñar el prototipo de la bomba manual | | | | | | | → | | | | |
| Construir la bomba manual | | | | | | | | → | | | |
| Diseño de experimentos para estudiarla eficiencia de Bomba Manual | | | | | | | | | → | | |
| Exposición de resultado ante la autoridades | | | | | | | | | | → | |

Fig. 4 Gantt chart

The benefits of the proposal are intended to support CONAGUA to regulate, control and protect the aquifers by avoiding the runoff of water. The strategies: through a mapping by regions and zones where the pumps registered with a serial number will be installed and categorically distributed in marginalized areas without drinking water, with which the project is identified.

**Phase IV. Execution**

In this phase, the construction of the Engineering Design Process begins. In this phase, the generic and specific skills to be developed are applied.

The model proposed in the previous phases is built and the pertinent resources are sought to solve the problem. Figure 5 illustrates some principles of the mechanics of the fluids that will be used for the construction of the manual pump for the extraction of well water at "N" depth.

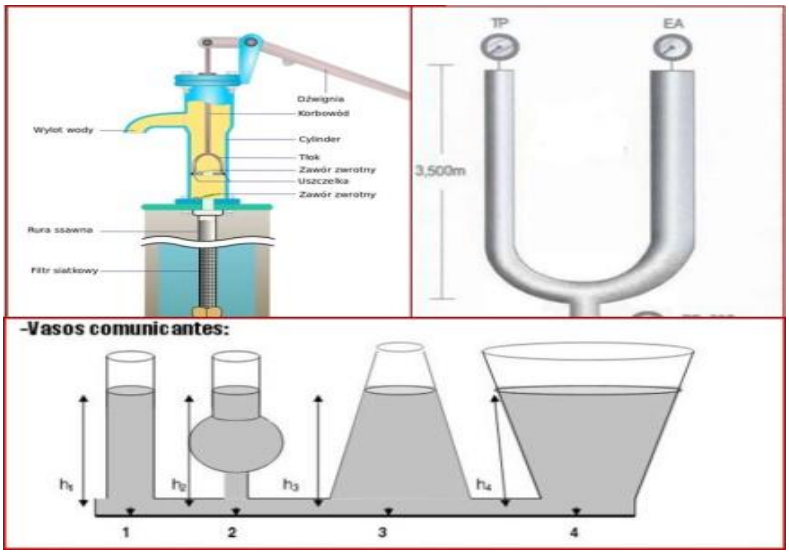


Fig. 5 Principles of Fluid Mechanics

The engineering design process continues with the design of the special piston that is required to operate the pump suction in a closed system to avoid pressure losses in order to take care of the efficiency of the pump. Figure 6 shows the design of a special piston for the suction system of the manual pump.

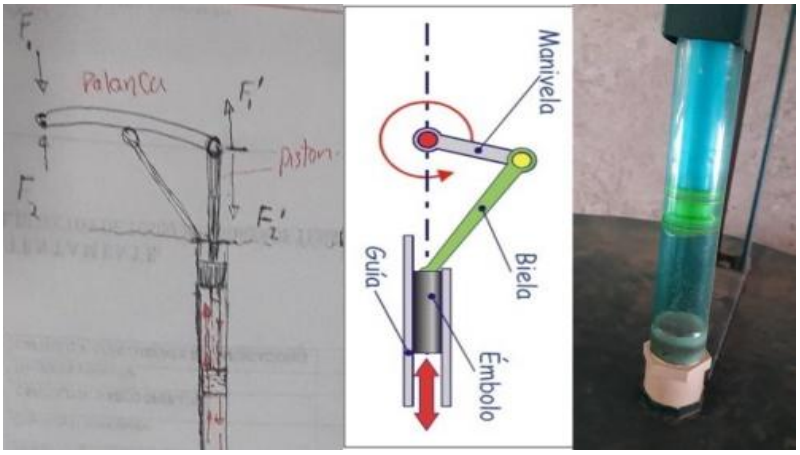


Fig. 6 diagrams of the design of the special suction piston

In figure 7 the engineering design work is visualized using the technology for the manufacture of the part of the piston rod that will allow the sealing of the suction system (using special software of optimal mechanical design) and for the manufacture of the part used a special 3D printer.

Fig 7. Modeling and manufacturing of the piston rod

Figure 8 shows the process in the assembly of parts for the manufacture of the manual pump. Actions that put engineering design into practice, it is not a finished product but a methodology that relies on knowledge, inventiveness, creativity and awareness of the concept of urgency, to visualize a real problem, formulate it in technical terms , explore possible solutions, evaluate alternatives, propose one or more ways or ways of solution, evaluate the possible processes that need to be used and their corresponding results, select one of the best solutions based on a set of criteria, execute the necessary actions to carry out a particular proposal and evaluate the process and results of each and every one of the actions, permanently making adjustments and corrections and issuing judgments and recommendations that are based on facts, preferably quantifiable.

Fig. 8 hand pump assembly process

**Phase V. Evaluation**

In this phase, the construction of knowledge is put into practice: knowing how to know-knowing how to do-knowing how to be. The teacher is attentive to the difficulties and opportunities that arise, guides the students in case they need readjustments in their plan and requests progress of the project, which are evaluated and, if necessary, make the pertinent adjustments to meet the planned objective in time and form. Applies a value judgment in the labor-professional, social and investigative context. The evaluation is carried out in three interdependent dimensions: self-evaluation, co-evaluation and hetero-evaluation. In this phase, it is a process of discussion, validation and refinement of schemes and approaches made in previous phases. It aims to integrate students in an active-collaborative process and debate; where questions about the phenomenon are constructed in research and critical construction of propositions and arguments.

In order to test the optimal operation of the project, specialized simulation software is used to check the mechanical design of the manual pump, in figure 9 the simulation is displayed.

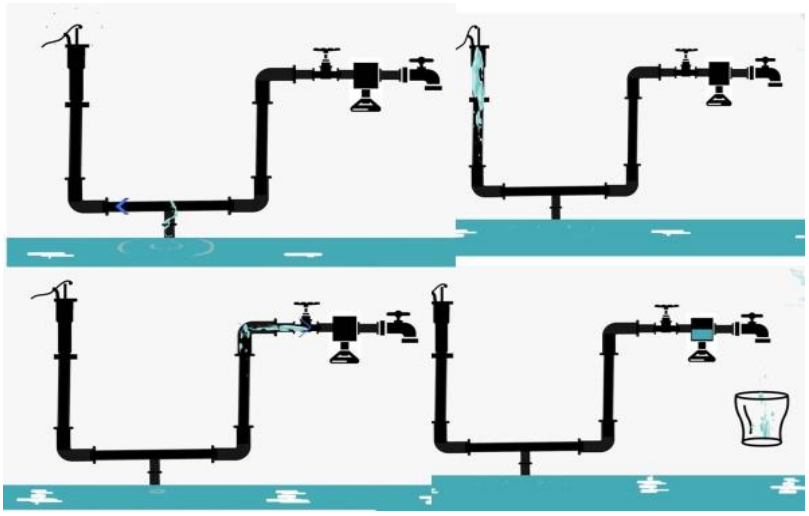

Fig. 9 Simulation of the hydraulic circuit for the study of the fluid mechanics of the Hand Pump

**Phase VI. Socialization of the learning process and problem solving**

The students present the results of the project, which allows them to show the development of competencies: engineering design, oral and written communication. The strategy was to propose to the group the dissemination of the project, participate in student events: conferences, forums, technological innovation. Spaces where they can disseminate their experiences of the active-collaborative learning process based on integrative-training projects. The teacher coordinates the evaluation in plenary through an evaluation rubric, where three interdependent dimensions are focused on the process: self-evaluation, co-evaluation and hetero-evaluation. In an environment of active-collaborative learning construction and continuous improvement. Figure 10shows the experimentation of the optimal operation of the manual pump in interaction with society

Fig. 10. Experimenting the Pump in the Field

Student participation in forums, Science and Technology contest and technological innovation. In figure 11 the students and teacher are visualized participating in academic-social events.

Fig. 11 Socialization of the learning process

## 4. Results and Discussion

The results report findings, within the framework of a learning model based on integrative-formative projects located in a context of interest to the student. The intention of this methodology was to investigate and generate a dynamic, capable of achieving inclusion in students and the development of competencies in real environments, facing authentic problems that demand challenges when requesting mental and physical effort.

The findings found during the development of the methodology at different times and scenarios are set out below:

**Moment1**, the approach to the problem situated in a context, causes interest in the students and they accept the challenge demanded by the project, they get involved in planning activities, they actively participate in the presentation of their ideas (sketches and hypotheses representative of the project) , debate and defend their ideas, reach a consensus in a collaborative work to make optimal decisions.

**Moment 2**, students get involved in their learning process in view of the need to collect information with the purpose of knowing the research phenomenon and delving into its fundamentals. In this phase, prior knowledge is articulated with what is currently in process to be applied later, in this case they integrate the competencies of the subjects (fundamentals of research, sustainable development, fluid mechanics, research workshop, hydraulics, instrumentation, workshop II, formulation and evaluation of projects). The brainstorming methodology is applied and the first approaches to the solution are constructed and exposed through sketches that express the cognitive and metacognitive structure of the student. They pose and restate hypotheses in an environment of discussion and debates mediated by the teacher.

Moment3, the students make the project their own, they get involved considering the problem conditions, they carry out the planning with the teacher's guidance. They are organized as a team and a representative team is selected that they appoint as the engineering staff to coordinate and follow up on the activities so that they are carried out in a timely manner. Moments that expose the collaborative group work in the students, the teacher has the role of promoter in the presentation of ideas, stimulating the participation of the students and encouraging the establishment of hypotheses and justifications.

Moment4, exposes the engineering design process of the hand pump, when designing and manufacturing special pieces to meet the project objective "the extraction of water from the aquifers at a depth" N. Moments that expose the objective of the training process for future engineers, the construction and development of basic, generic and design skills in engineering.

Moment5, the construction of knowledge is put into practice: knowing-knowing-knowing-knowing-knowing how to be, simulation is exposed in specialized software of the optimal mechanical design of the manual pump and the mechanics of the fluid in the water extraction process. Where the evaluation is carried out in three interdependent dimensions: self-evaluation, co-evaluation and hetero-evaluation.

Moment 6, students present the results of the project to society, which allows them to show the development of competencies: engineering design, oral and written communication. The participation of students in this type of academic and social events allows the teacher to carry out a comprehensive evaluation process in three interdependent dimensions: self-evaluation, co-evaluation and hetero-evaluation.

The results obtained refer to what was proposed by Dr. Sergio Tobón where he describes the competencies, from a socioformation approach. The competencies have the following key characteristics: They are performances or actions in the environment, they are based on knowledge management, they articulate various knowledge: knowing how to be, knowing how to do, knowing how to know and how to live together, they focus on solving problems in the context, they are based In solid values, such as responsibility, honesty, respect and equity, they seek suitability, focusing on meeting pre-established or agreed-upon quality criteria in the context (Tobón, 2013, 2014).

## 5. Conclusions

The evidences report encouraging findings, when working on a learning model based on integrative-formative projects situated in the professional interest of the student. The intention of this methodology was to generate a dynamic, capable of achieving inclusion in students, commitment and the development of competences in real environments, facing authentic problems that demand challenges and physical-mental effort. Gift of the activities and actions carried out that can be considered as a source of motivation necessary to develop the skills demanded by society and the business sector.

## 6. Thanks

We are grateful to the directors of the National Technological Institute of Mexico/Tantoyuca for facilitating and promoting this type of research projects and collaborative-active-learning spaces that allow the construction of a new paradigm in the educational process of students. A special thanks for collaboration to the University of Matanzas Cuba for promoting this category of research that contributes to continuous improvement and the development of professional skills.

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**1.** Graphics