Using ICT tools to solve fluid dynamics problems at intermediate level engineering studies

Uso de TICs para la resolución de problemas de dinámica de fluidos en estudios de ingeniería en nivel intermedio

Roberto Flores Velázquez[1*], Nadia Lara Ruíz[1],
Silvia Mendoza Vergara[1] y Rogelio Sotelo Boyás[2]

[1]Facultad de Ciencias Químicas e Ingeniería, Universidad Autónoma del Estado de Morelos
Av. Universidad No. 1001, Col. Chamilpa, Cuernavaca, Morelos, 62209, México
[2]Escuela Superior de Ingeniería Química e Industrias Extractivas, Instituto Politécnico Nacional,
Av. Instituto Politécnico Nacional, Col. Lindavista, Gustavo A. Madero, 07700 Ciudad de México, México
[*]roberto.flores@uaem.mx

KETWORDS:

Information and communication technologies, spreadsheets, first law of thermodynamics, fluid flow calculations, engineering education

ABSTRACT:

Engineering students need to acquire a variety of hard and soft skills while attending college. Furthermore, in order to advance in their career, students must learn how to effectively use information and communication technologies (ICT) to tackle a variety of engineering issues. Spreadsheets, usually found in Microsoft Excel, are among the ICT that are easiest to access and use. Nevertheless, its instruction and use in engineering courses at universities have not been well developed, and this is frequently because of the teachers' inability to apply it because they lack the necessary expertise. In this manuscript, it is demonstrated how students can create a Microsoft Excel program that solves representative cases of fluid dynamics in a piping system studied at an intermediate university level. Examples of these cases include pump power, pipe diameter, and flow rate calculation using the First Law of Thermodynamics. Students must be able to integrate a robust database with the properties and characteristics of the pipe material and its accessories, as well as the solution technique with the calculations and results presented in an easy and straightforward manner, for the application to operate properly. Finally, students can easily use the program and investigate how operating variables affect fluid flow through pipes by integrating Microsoft Excel's add-ins and creating macros.

PALABRAS CLAVE:

Tecnologías de la información y la comunicación, hojas de cálculo, primera ley de la termodinámica, cálculos de flujo de fluidos, educación en ingeniería

RESUMEN:

Los estudiantes de ingeniería necesitan adquirir una variedad de habilidades duras y blandas mientras asisten a la universidad. Además, para avanzar en su carrera, los estudiantes deben aprender a utilizar eficazmente las tecnologías de la información y la comunicación (TICs) para abordar una variedad de cuestiones de ingeniería. Las hojas de cálculo, normalmente usadas en Microsoft Excel, se encuentran entre las TICs a las que es más fácil acceder y que son más sencillas de utilizar. Sin embargo, su enseñanza y uso en los cursos de ingeniería en las universidades no ha sido bien desarrollado, y esto frecuentemente se debe a la incapacidad de los profesores para aplicarlo por carecer de la experiencia necesaria. En este documento se demuestra cómo los estudiantes pueden crear un programa en Microsoft Excel que resuelve casos representativos de dinámica de fluidos en un sistema de tuberías estudiado en un nivel universitario intermedio. Algunos ejemplos de estos casos incluyen: potencia de una bomba, diámetro de tubería y cálculo de caudal utilizando la Primera Ley de la Termodinámica. Los estudiantes deben ser capaces de integrar una base de datos robusta con las propiedades y características del material de la tubería y sus accesorios, así como la solución con los cálculos y resultados presentados de manera fácil y directa, para que la aplicación funcione correctamente. Finalmente, los estudiantes pueden usar

DOI: 10.30973/progmat/2026.18.2/1

fácilmente el programa e investigar cómo las variables operativas afectan el flujo de fluido a través de tuberías mediante la integración de complementos de Microsoft Excel y la creación de macros.

• Recibido: 23 de mayo de 2026 • Aceptado: 9 de octubre de 2026 • Publicado en línea: 2 de junio de 2026

1. INTRODUCTION

Learning Information and Communication Technologies (ICT) play a significant role in the university education of engineering students. Using such tools effectively reduces the time and effort required to tackle complex engineering issues requiring iterative computations or time-consuming processes. Undergraduate education systems now require instructors' abilities to learn and effectively use ICT tools (including spreadsheets and text processors like Microsoft Excel and Microsoft Word, respectively) for teaching and learning purposes. Furthermore, to integrate Industry 4.0 and engineering programs, academic institutions and universities must add digitization skills with the aid of ICT tools and the usual hard and soft skills. ICT tools are essential when the teacher's primary goal is the development of creative abilities where to apply basic knowledge [1-3]. Employers today expect new university graduates interested in engineering professions to be skilled users of ICT tools. For example, in the case of Microsoft Excel, they can manage inventory, create a database with drop-down lists, develop interactive dashboards for a nice presentation of data and results, and program macros, among other skills.

Nevertheless, one of the most significant issues in using ICT tools in universities is their scarcity due to their sophistication or the high cost of their commercial license. For that, universities should first focus on commonly used ICT, such as spreadsheets, or free licenses for process simulators, like DWSIM, and incorporate them into a new curriculum dealing with computational numerical methods, heat transfer, fluid mechanics, and transport phenomena to develop technical competences and model simulation skills. Here, the difficulty lies in the teachers' limited knowledge of ICT tools for classroom education and their inability to incorporate ICT tools into their subjects. This situation is compounded by the fact that many university engineering professors learnt in a traditional approach, with an emphasis on manual problem-solving and limited integration of digital technologies into the teaching and learning process. Several studies have indicated that the lack of formal ICT training and the lack of digital skills among higher education professors represent a limitation to educational innovation in engineering [1, 4]. The absence of systematic training programs, coupled with the overload of academic responsibilities, restricts professors' willingness to invest time in mastering tools such as Microsoft Excel. Furthermore, resistance to methodological change, as well as the perception that redesigning materials requires additional effort, generates pedagogical barriers that delay the adoption of learning support technologies [3]. To overcome these limitations, several strategies are proposed, including practical workshops focused on teaching with spreadsheets, the creation of repositories containing templates, macros, and examples applicable to typical engineering problems, and the promotion of peer-to-peer learning communities where more experienced instructors support their colleagues [5]. The gradual integration of these tools, initially combining traditional methods with spreadsheet exercises, can facilitate the transition and ensure a positive impact on both teaching and student learning.

Compared to commercial simulators, such

as Aspen Plus, ChemCAD, and so on, Microsoft Excel is much easier to use and access at a bachelor's level. Furthermore, it must be taken into account that commercial chemical process simulators are professional tools that require arduous training to be adequately used, and this is usually not available at an academic level worldwide. Microsoft Excel has plenty of built-in tools that make the software suitable for developing easy simulations of industrial processes [5-11].

On the other hand, students learn the established methods' sequence by designing and programming a spreadsheet to calculate variables in real-world engineering challenges. They must give all the instructions without skipping a single step because doing so will prevent them from arriving at the intended or correct solution. In addition, in most cases, they should include a database with the physical properties of chemical compounds, construction materials, and accessories so the same program can select the parameters required to solve the problem. After creating their program, students can run simple simulations by adjusting operating conditions to understand the physical behavior of the problem under study. For example, in the case of fluid dynamics, it is possible to realize the effect of fluid viscosity on the pump's power and/or flow rate under established conditions.

The present work demonstrates how college students studying engineering at the intermediate level may generate automatic calculations for different scenarios on fluid dynamics utilizing ICT resources, in this instance, with the creation of spreadsheets in Microsoft Excel. This case study uses the mechanical energy equation, derived from the First Law of Thermodynamics principles, to analyze how fluids move through a pipe system. Students must be able to use the arithmetic functions of Microsoft Excel, adapt its built-in tools to simplify the solution of the problems raised, and program macros so the calculations are automatically executed once the variables of the processes have been introduced in the corresponding cells. Of course, this program is far from replacing commercial software specialized in fluid transport, such as Ansys Fluent and Aspen Plus, among others. Its sole purpose is to introduce students to the intelligent use of ICT tools to address problems encountered during their engineering studies and develop their design and programming skills in standard software.

The structure of this manuscript is as follows: in the Theoretical Basis section, the principles of the First Law of Thermodynamics and the mechanical energy equation applied to pipe flow are explained; next, the typology of the most common fluid flow problems in engineering is described; in the Microsoft Excel Program Design section, the development of the tool is presented step by step, including the calculation of pipe diameter, flow velocity and pumping power, based on functions such as "GoalSeek" and macros; then, in the Program Applications section, three practical examples are developed that illustrate the use of the spreadsheet in different scenarios; finally, the results section of the students' perception of the use of the tool and its impact on the learning of fluid dynamics is presented.

2. THEORETICAL BASIS

Pipe flow analysis is based on the First Law of Thermodynamics, also known as the General Principle of Conservation of Energy: "*Energy cannot be created or destroyed during a process; it can only change form*". From here, the General Equation of Energy Balance is written as:

$$\begin{matrix}\text{Final Energy}\\ \text{in the system}\end{matrix} - \begin{matrix}\text{InItial Energy}\\ \text{in the system}\end{matrix} = \begin{matrix}\text{Net Transferred Energy}\\ \text{to the system}\end{matrix} \quad (1)$$

Where:

$$\text{Initial Energy in the system} = U_i + E_{ki} + E_{pi} \quad (2)$$

$$\text{Final Energy in the system} = U_f + E_{kf} + E_{pf} \quad (3)$$
$$\text{Transfered Energy} = Q - W \quad (4)$$

U : internal energy
E_k : kinetics energy
E_p : potential energy
Q : heat
W : work

Replacing the terms:

$$(U_f - U_i) + (E_{cf} - E_{ci}) + (E_{pf} - E_{pi}) = Q - W \quad (5)$$

In the case of open systems with steady state mass input and output, the net rate of work done by the system on the surroundings is:

$$\dot{W} = \dot{W}_s + \dot{W}_{fl} \quad (6)$$

Where $\dot{W}_s$ is shaft work, which is the one that makes or receives the fluid in some mobile part within the system. $\dot{W}_{fl}$ is flow work, which is the work required to move a fluid into or out of a system:

$$\dot{W}_{fl} = P_f \cdot \dot{V}_f - P_i \cdot \dot{V}_i \quad (7)$$

Where:

P: pressure
$\dot{V}$: volumetric flow

If the fluid is liquid and the change in its density from the input to output of the system is negligible, it is obtained:

$$\dot{W}_{fl} = (P_f - P_i) \cdot \dot{V} = \Delta P \cdot \dot{V} \quad (8)$$

When fluids are transported through pipelines, negligible quantities of heat are transferred to or from the surrounding environment ($\dot{Q}=0$). Also, temperature changes little from inlet to outlet, and there are no phase changes or chemical reactions; therefore $\Delta U = 0$. Nevertheless, there are significant energy losses due to the fluid's friction against the pipe walls and its passage through accessories (valves, elbows, unions, reducers, etc.). This energy dissipation is known as friction losses, $\dot{m} \cdot \hat{F}$.

Then, the general energy equation for open systems can be written:

$$\Delta P \cdot \dot{V} + \Delta \dot{E}_k + \Delta \dot{E}_p + \dot{m} \cdot \hat{F} = \dot{W}_s \quad (9)$$

Where:

$$\Delta E_k = \frac{1}{2} \dot{m} \cdot \Delta u^2 \quad (10)$$
$$\Delta \dot{E}_p = \dot{m} \cdot \Delta z \quad (11)$$

$\dot{m}$: mass flow
u: mean linear velocity
z: height

Also, the volumetric flow can be written in terms of the mass flow using the density :

$$\dot{V} = \frac{\dot{m}}{\rho} \quad (12)$$

Replacing:

$$\Delta \frac{P \cdot \dot{m}}{\rho} + \frac{1}{2} \dot{m} \cdot \Delta u^2 + \dot{m} \cdot \Delta z + \dot{m} \cdot \hat{F} = \dot{W}_s \quad (13)$$
$$\frac{\Delta P}{\rho} + \frac{\Delta u^2}{2} + g \cdot \Delta z + \hat{F} = \frac{-\dot{W}_S}{\dot{m}} \quad (14)$$

The last is known as the Mechanical Energy Equation.

Friction losses through pipes are calculated with:

$$\hat{F} = \left(f \frac{L}{D} + \sum K_L \right) \frac{u^2}{2} \quad (15)$$

Where:

f: friction factor (Darcy-Weisbach factor)
L: pipe length
D: pipe internal diameter
$\sum K_L$: minor losses in accessories

Before calculating the friction factor, f, the Reynolds number, which is a ratio between the *inertial forces* and the *viscous forces* in the fluid, is used to determine whether the fluid transportation through the pipe is laminar or turbulent:

$$\text{Re} = \frac{\text{inertial forces}}{\text{viscous forces}} = \frac{\rho \cdot u \cdot D}{\mu} = \frac{u \cdot D}{\nu} \quad (16)$$

Where:

ρ: fluid density (kg/m^3);
u: mean linear velocity (m/s);
D: geometry characteristic length (diameter in this case, in m);
μ: fluid dynamic viscosity (Pa·s);
ν: kinematic fluid viscosity (m^2/s).

It is preferable to have accurate Reynolds number values for laminar, transitional, and turbulent flows, and the widely accepted limits are:

$\mathrm{Re} \leq 2300$	laminar flow
$2300 \leq \mathrm{Re} \leq 4100$	transitional flow
$\mathrm{Re} \geq 4100$	turbulent flow

If the flow is laminar, the coefficient of friction is calculated with:

$$f = \frac{64}{\mathrm{Re}} \tag{17}$$

If the flow is turbulent or transitional, in addition to the Reynolds number, the relative roughness (ϵ / D) of the pipe material needs to be known. Then, traditionally the Moody Diagram is used to know the friction factor; however, the Colebrook equation modified by S. E. Haaland, which gives values with differences of $\pm 2\%$ with respect to the Moody Diagram can also be used:

$$f = \left(\frac{1}{-1.8 \log_{10} \left[\frac{6.9}{\mathrm{Re}} + \left(\frac{\epsilon / D}{3.7} \right)^{1.11} \right]} \right)^2 \tag{18}$$

Minor losses, K_L, represent the pressure drop or energy loss of the fluid as it passes through an accessory. These values have been determined experimentally and are reported in different bibliographical references related to fluid mechanics.

3. TYPICAL PROBLEMS IN THE AREA OF FLUID FLOW

In the design and analysis of fluid flow systems in pipelines, there are typically three types of problems, assuming that the difference in pressure and height between the initial and final points, the density and viscosity of the fluid, and the roughness of the pipe and accessories included in the system are specified:

I. **Determination of the pump's power**: when it is set the volumetric flow, the length and diameter of the pipe.
II. **Determination of the flow velocity and/or volumetric flow:** it happens when the length and diameter of the pipe are indicated in addition to the power of the pump.
III. **Determination of the pipe's diameter:** it occurs when the length of the pipe, the volumetric flow and the power of the pump are known.

Problems of the first type are solved by a direct procedure. The second and third types of problems usually come up in engineering design. For example, choosing the pipe diameter that reduces the total cost of building and pumping requires an iterative process.

In the second type of problems, the diameter is known, but the flow velocity and volumetric flow are not, so it is not possible to figure out the Reynolds number and identify whether the flow is laminar, transitional, or turbulent. For this reason, the mechanical energy equation is solved by first assuming a flow velocity and then solving for each of its components. The flow velocity is correct if the mechanical energy conditions are met, either by equating this equation to zero or by computing another part of the equation, such as friction losses. Otherwise, an alternative flow velocity is proposed.

In problems of the third type, the diameter is unknown, making it impossible to calculate the Reynolds number and relative roughness. Consequently, calculations begin with the assumption of a pipe diameter. The criteria of the mechanical energy equation are compared (as previously stated), and calculations are repeated iteratively with a different pipe diameter until convergence is reached.

4. PROGRAM DESIGN IN MICROSOFT EXCEL

The program in Microsoft Excel uses hyperlink buttons to browse across spreadsheets. At the beginning, a menu shows the types of fluid flow problems that have already been stated and that the program can solve, as shown in Figure 1. The diameter option allows calculating the diameter of the pipe, the velocity option allows the calculation of the flow rate of the fluid, and the pump power option determines the required power of a pump to transport a fluid. In each case, the remaining system variables must be specified.

4.1. Pipe diameter calculation

To calculate the diameter of a pipe, the screen shown in Figure 2 is displayed. The cells shown in white are the system variables needed to compute a pipe's diameter using the mechanical energy equation. As the system variables are incorporated, the spreadsheet automatically calculates the yellow cells. The blue cells indicate pipe material properties that are determined by the program when the pipe material is selected as shown in Figure 3. The material selection is made by means of a drop-down list, as its shown in Figure 3, and it has as options steel schedule 40 and 80, copper type K, and cast iron.

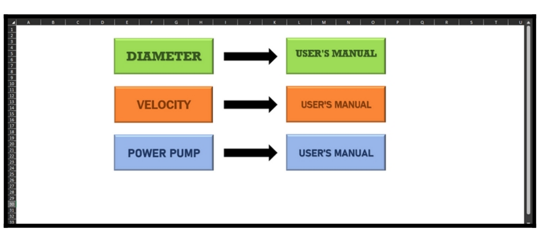

Figure 1. Main menu of the created program.

Using an iterative procedure, the diameter is determined. In this instance, the solution strategy involves suggesting a diameter value and calculating friction losses with the equation:

$$\hat{F}=\left(f\frac{L}{D}+\sum K_L\right)\frac{u^2}{2} \tag{19}$$

As well as with the equation of mechanical energy:

$$\hat{F}=\frac{-\dot{W}_S}{\dot{m}}-\frac{\Delta P}{\rho}-\frac{\Delta u^2}{2}-g\cdot\Delta z \tag{20}$$

The program is intended for use with incompressible liquids and a constant pipe diameter, so the change in kinetic energy is negligible:

$$\hat{F}=\frac{-\dot{W}_S}{\dot{m}}-\frac{\Delta P}{\rho}-g\cdot\Delta z \tag{21}$$

With the proposed diameter, the flow velocity in cell G6 is calculated:

$$u=\frac{4\cdot\dot{V}}{\pi\cdot D^2} \tag{22}$$

```
G6 = (4*D6)/(PI()*I2^2)
```

Note that for the value of π, the Excel function PI() (which returns the value with a precision of 15 digits) is used to perform the calculations with greater accuracy.

Next, in cell H6 the Reynolds number is calculated.

```
H6 = (D3*G6*I2)/D4
```

Depending on the magnitude of this number, the program informatively indicates in cell H7 if there is a laminar, transitional, or turbulent flow with the following conditional instruction:

```
H7 = IF(Table2[Re]<2300,
"Laminar Flow", IF(Table2[Re]>4100,
"Turbulent Flow", "Transitional Flow"))
```

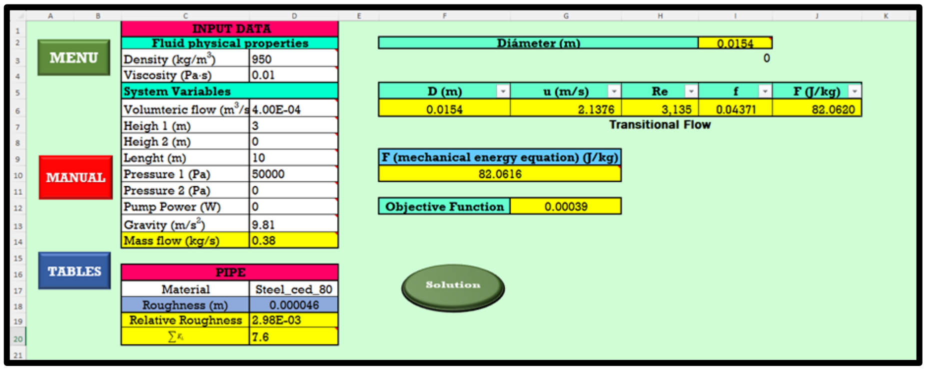

Figure 2. Menu to calculate the diameter of a pipe.

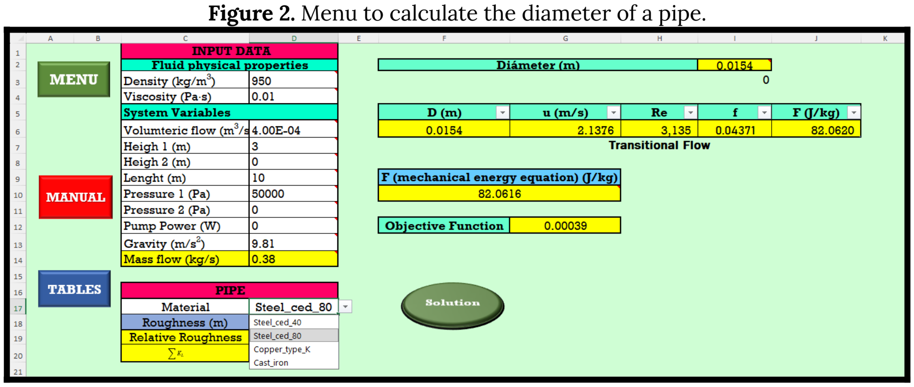

Figure 3. Selection of the pipe material.

Depending on this value, the program defines how to calculate the coefficient of friction, f, in cell I6 using the following conditional statement:

```
I6 = IF(H6<2100, 64/H6, (1/(-
1.8*LOG10(6.9/H6+(E20/3.7)^1.11)))^2
```

On the other hand, the global coefficient of minor losses $\left(\sum K_L\right)$ is calculated by selecting the type and quantity of elbows, as well as the types and quantities of valves used in the piping system in the TABLES section as indicated in the Figure 4. It can be seen that the choice of accessories is made via drop-down lists that also indicate their quantity.

To obtain the solution, an objective function consisting of contrasting the calculated friction losses of the pipe with the value derived from the mechanical energy equation is established:

$$\Phi=\hat{F}_{\text{pipeline}}-\hat{F}_{\text{mechanic energy}} \tag{23}$$

Where:

$$\hat{F}_{\text{pipeline}}=\left(f\frac{L}{D}+\sum K_L\right)\frac{u^2}{2} \tag{24}$$

$$\hat{F}_{\text{mechanic energy}}=\frac{-\dot{W}_S}{\dot{m}}-\frac{\Delta P}{\rho}-g\cdot\Delta z \tag{25}$$

$\hat{F}_{\text{pipeline}}$ is calculated in cell J6:

```
J6=(I6*D9/I2+D20)*(G6^2/2)
```

$\hat{F}_{\text{mechanic energy}}$ is calculated in cell F10:

```
F10=D12/D14+(D11-D10)/D3-D13*(D8-D7)
```

In turn, the objective function ㅎ is calculated in cell G12:

```
G12=J6-F10
```

The procedure is iterative, and the solution is found when the objective function is equal to zero, $\Phi=0$.

To avoid iterations, in Microsoft Excel there is the “GoalSeek” option found in the Hypothesis Analysis tool in the Data section.

It should be noted that this tool was developed for accounting and administrative purposes; however, it is perfectly adequate to find the diameter of the program.

Once the "GoalSeek" function has been selected, the dialog box shown in Figure 5 appears. In said box, cell G12 (where the calculation of the objective function is found) is equal to 0, changing the value from cell I2 (where the pipe diameter is proposed).

This action can be automated with the design of a macro, which is listed in Figure 6. In this way, if the problem to be solved with the system variables has a solution, by pressing the solution button the program finds the diameter that satisfies the Objective Function.

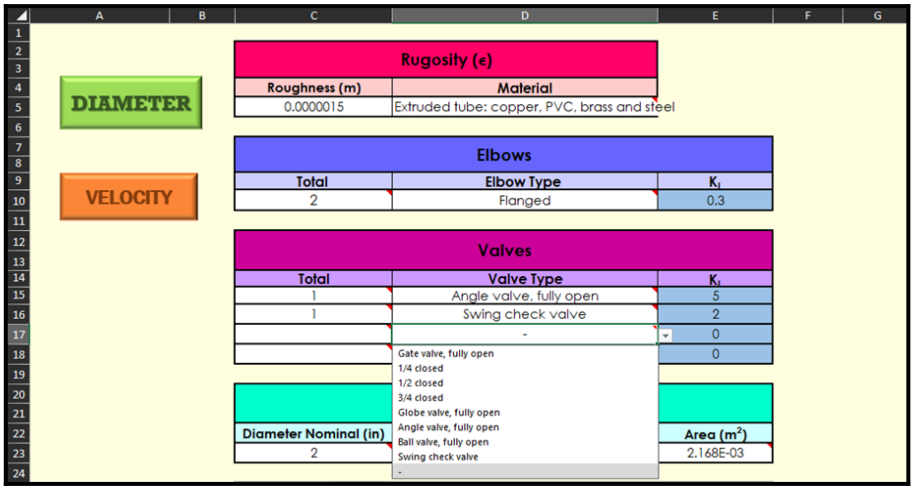

Figure 4. Selection of accessories in the pipeline system.

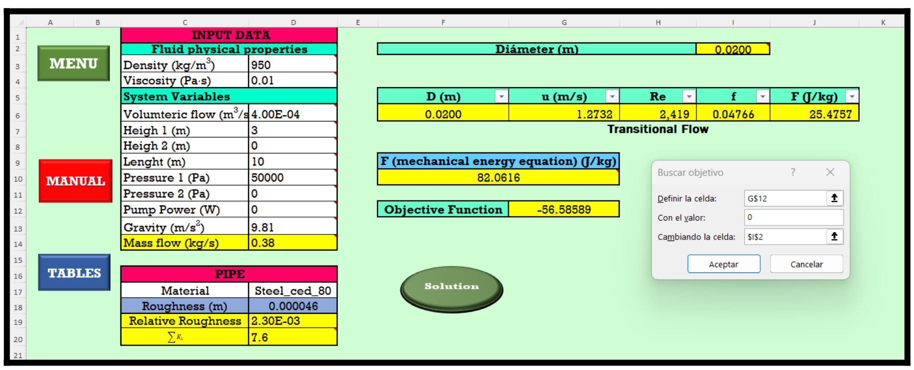

Figure 5. Use of the "GoalSeek" function to find the diameter of the pipeline system.

```
Sub Solución()
'
' Solución Macro
' Cálcula la velocidad de flujo de un sistema de tuberías
'

'
    Range("I2").Select
    ActiveCell.FormulaR1C1 = "1"
    Range("I3").Select
    Application.CutCopyMode = False
    Application.CutCopyMode = False
    Application.CutCopyMode = False
    Range("G12").GoalSeek Goal:=0, ChangingCell:=Range("I2")
    Range("H15").Select
```

Figure 6. Macro structure to find the diameter of the pipeline system

4.2. Flow Velocity Calculation

In the case of flow velocity calculation, the screen is shown in Figure 7. As in the previous case, the cells containing the input variables are white, so the physical properties of the fluid, system variables, and pipe material and diameter must be specified. Calculations made by the program are shown in yellow cells, and cells in blue are values selected by the program via drop-down lists for pipe material and nominal diameter, as noted above. Likewise, the type and quantity of accessories is indicated as previously explained.

After entering all of the input variables, the problem is solved iteratively, beginning with a flow rate proposal.

With the proposed velocity, the Reynolds number is calculated in cell G6:

$$\mathrm{Re}=\frac{\rho\cdot u\cdot D}{\mu} \tag{26}$$

```
G6= (D3*F6*D19)/D4
```

In an informative way, the program indicates if there is laminar, transitional, or turbulent flow in cell G7:

```
G7 = IF(G6<2300, "Laminar Flow",
 IF(G6>4100, "Turbulent Flow",
     "Transitional Flow"))
```

The friction coefficient, *f*, is calculated in cell H6 with the conditional statement previously indicated, and depending on the Reynolds number:

```
H6=IF(G6<2100, 64/G6,
(1/((-1.8)*(LOG10(6.9/G6+(((D21)/
3.7)^1.11))))^2))
```

Then, in cells I6, F10 and G12, are calculated $\hat{F}_{\text{pipeline}}$, $\hat{F}_{\text{mechanic energy}}$, and the objective function, Φ, respectively.

$$\hat{F}_{\text{pipeline}}=\left(f\frac{L}{D}+\sum K_L\right)\frac{u^2}{2} \tag{27}$$

```
I6 =(H6*D9/D19+D23)*(F6^2/2)
```

$$\hat{F}_{\text{mechanic energy}}=\frac{-\dot{W}_S}{\dot{m}}-\frac{\Delta P}{\rho}-g\cdot\Delta z \tag{28}$$

```
F10 =D12/D14-(D11-D10)/D3-D13*(D8-D7)
```

$$\Phi=\hat{F}_{\text{mechanic energy}}-\hat{F}_{\text{pipeline}} \tag{29}$$

```
G12 =I6-F10
```

The solution is found when with the proposed velocity the objective function is equal to 0.

To find the solution, it can be used again the "GoalSeek" function as it is shown in Figure 8.

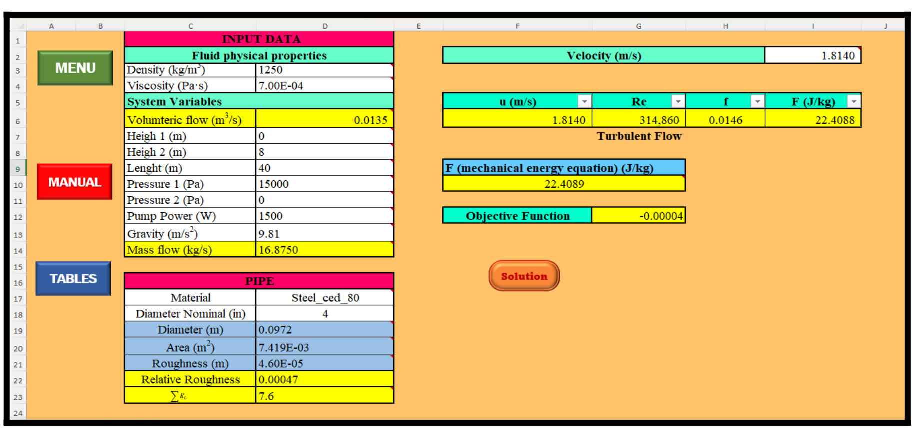

Figure 7. Menu to calculate the flow velocity of the pipeline system.

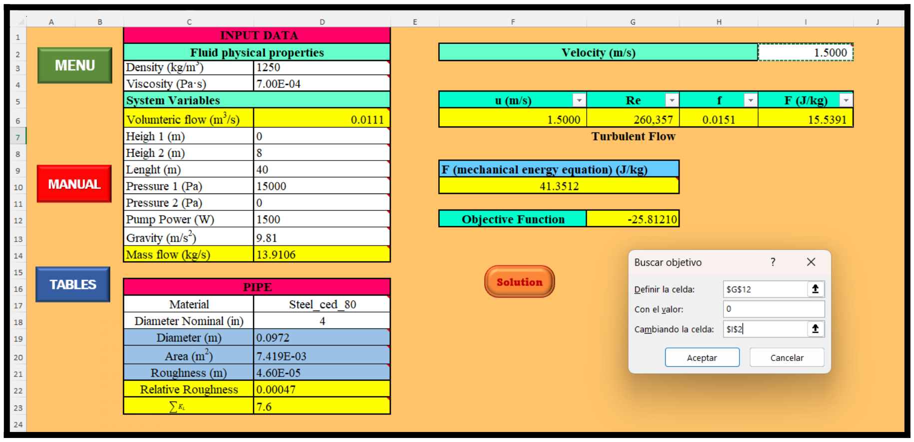

Figure 8. Use of the "GoalSeek" function to find the flow velocity of the pipeline system

Once the "GoalSeek” option has been selected in the dialog box, cell G12 (where the objective function is calculated) is selected and set equal to 0 by changing the value of cell I2 (which contains the proposed velocity). Likewise, a macro that suggests an initial value and executes the “GoalSeek” application is created (Figure 9).

4.3. Pump Power Calculation

The calculation of the power of the pump is carried out in the sheet shown in Figure 10.

In a similar way to the previous cases, in the white cells are introduced the physical properties of the fluid, the variables of the analysis system, as well as the material and nominal diameter of the pipe. The blue cells are values that the sheet obtains automatically with the pipe specifications and the database integrated into the program.

With the information entered in the spreadsheet, the calculations are made directly to estimate the power of the pump.

First, in cell F6, the flow velocity is calculated from the volumetric flow and the internal area of the pipe:

$$u=\frac{\dot{V}}{A} \tag{30}$$

```
F6 =D6/D19
```

Next, the Reynolds number is calculated in cell G6:

$$\mathrm{Re}=\frac{\rho\cdot u\cdot D}{\mu} \tag{31}$$

```
G6=(D3*F6*D18)/D4
```

In an informative way, the program indicates if there is laminar, transitional, or turbulent flow in cell G7:

```
G7 =IF(G6<2300, "Laminar Flow",
  IF(G6>4100, "Turbulent
Flow","Transitional Flow"))
```

The coefficient of friction, f, is calculated in cell H6 with the conditional statement previously indicated, and depending on the Reynolds number:

```
H6= IF(G6<2100, 64/G6,
(1/(-1.8*(LOG10(6.9/G6+
(D21/3.7)^1.11)))^2))
```

Next, in cell I6, the friction losses that occur in the pipe are calculated:

$$\hat{F}=\left(f\frac{L}{D}+\sum K_L\right)\frac{u^2}{2} \tag{32}$$

```
I6 =(H6*D9/D19+D23)*(F6^2/2)
```

The mass flow is determined in cell D13:

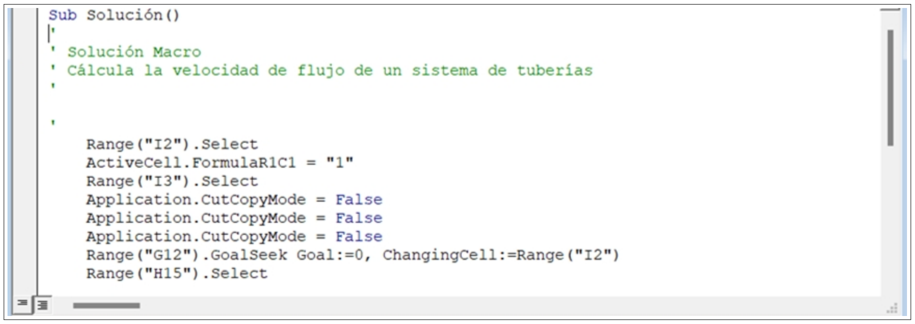

Figure 9. Macro structure to find the diameter of the pipeline system.

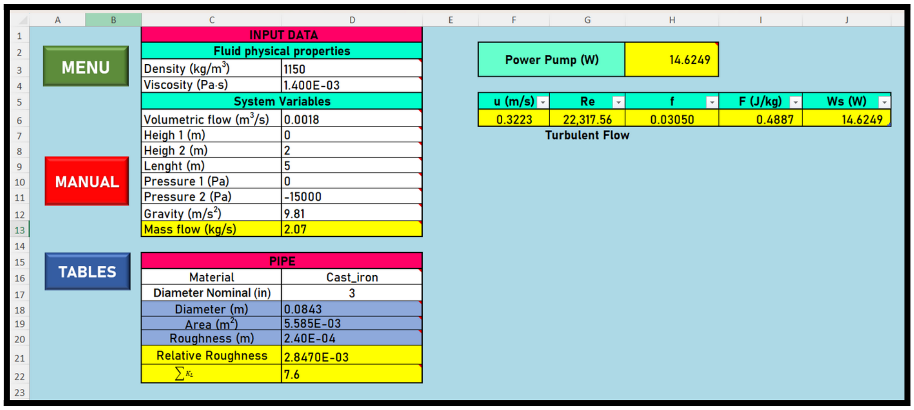

Figure 10. Menu to calculate pump power of the pipeline system

$$\dot{m}=\dot{V}\cdot \tag{33}$$

```
D13=D6*D3
```

Finally, the pump power is calculated in cell J6:

$$-\dot{W}_S=\dot{m}\left(\frac{\Delta P}{\rho}+g\cdot\Delta z+\hat{F}\right) \tag{34}$$

```
J6=D13*((D11-D10)/D3+D12*(D8-D7)+I6)
```

5. APPLICATIONS OF THE CREATED PROGRAM

Example 1. Pipe diameter calculation

It is desired to heat a high viscosity hydraulic oil using a heat exchanger. The oil is stored in a tank that is 3 m above the level of the heat exchanger and has a gauge pressure of 50 kPa. For its part, the heat exchanger operates at atmospheric pressure. The oil has a dynamic viscosity of 0.130 Pa·s and a density of 800 kg/m^3. It is desired to use a type K copper pipe with a length of 10 m and a volumetric flow of 0.0005 m^3/s is required. The system has a fully open angle valve, and a swing check valve as is shown in Figure 11. Determine the diameter of the pipe.

Solution

To solve the problem, the values of the physical properties of the hydraulic oil are inserted in units of the international system: density in kg/m^3, and dynamic viscosity in Pa·s. Similarly, the system variables are placed in the international system: volumetric flow (m^3/s), height 1 (m), height 2 (m), pipe length (m), pressure 1 (Pa), pressure 2 (Pa), pump's power (W), and pipe material. Everything is done in the white cells of the spreadsheet designed as shown in Figure 12. Finally, in the Tables section, the types of accessories and their quantity are selected as indicated in Figure 13.

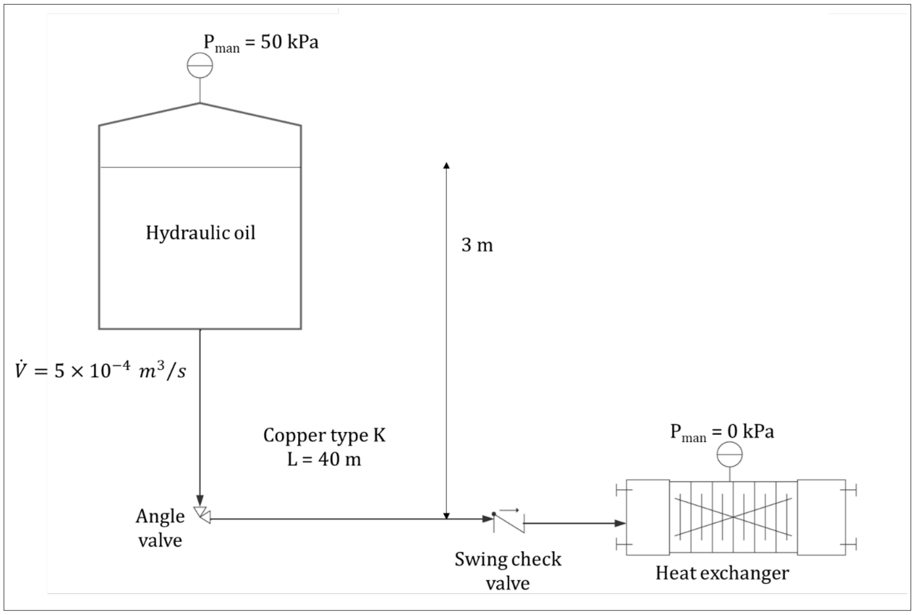

Figure 11. Flow diagram of Example 1.

Elbows		
Total	Elbow Type	K_L
0	-	0
Valves		
Total	Valve Type	K_L
1	Angle valve, fully open	5
1	Swing check valve	2
	-	0
	-	0

Figure 13. Selection of accessories to solve Example 1.

INPUT DATA	
Fluid physical properties	
Density (kg/m^3)	800
Viscosity (Pa·s)	0.13
System Variables	
Volumteric flow (m^3/s)	5.00E-04
Heigh 1 (m)	3
Heigh 2 (m)	0
Lenght (m)	10
Pressure 1 (Pa)	50000
Pressure 2 (Pa)	0
Pump Power (W)	0
Gravity (m/s^2)	9.81
Mass flow (kg/s)	0.4

Figure 12. Input of system variables to solve Example 1.

After executing the macro in the "Solution" button, the spreadsheet calculates the diameter in the yellow cells using the annotated data as is indicated in Figure 14.

The results obtained are:

1) Mass flow: 0.4 kg/s
2) Diameter: 0.0248 m
3) Flow velocity: 1.0389 m/s
4) Reynolds number: 156 (laminar flow)
5) Friction coefficient: 0.4044
6) Friction loss in pipeline: 91.9311 J/kg
7) Friction loss from the mechanic energy equation: 91.9300 J/kg
8) Objective function: 0.00006

Example 2. Calculation of flow velocity

A 500 W centrifugal pump is used to transport ethyl alcohol at 50 °C (sg = 0.78, μ= 7.0×10^{-4} Pa·s) from a tank located on the ground floor of a factory to a tubular reactor located 5 m above the tank (vertically). The reservoir has a gauge pressure of 150 kPa, and the reactor operates at atmospheric pressure. The flow is carried out through a 2-inch commercial steel pipe, schedule 40, and the installation has a length of 40 m with 4 threaded elbows, a swing check valve, and a ½ closed gate valve as indicated in Figure 15. Determine the flow velocity of the ethyl alcohol.

Solution:

To solve the problem, the values of the physical properties of ethyl alcohol at 50 °C are inserted in units of the international system: density in kg/m^3, and dynamic viscosity in Pa·s. Likewise, the system variables are also placed in the international system: height 1 (m), height 2 (m), pipe length (m), pressure 1 (Pa), pressure 2 (Pa), pump's power (W), pipe material and nominal diameter. Everything is done in the white cells of the spreadsheet designed as shown in Figure 16. Finally, in the Tables section, the types of accessories and their quantity are selected as indicated in Figure 17.

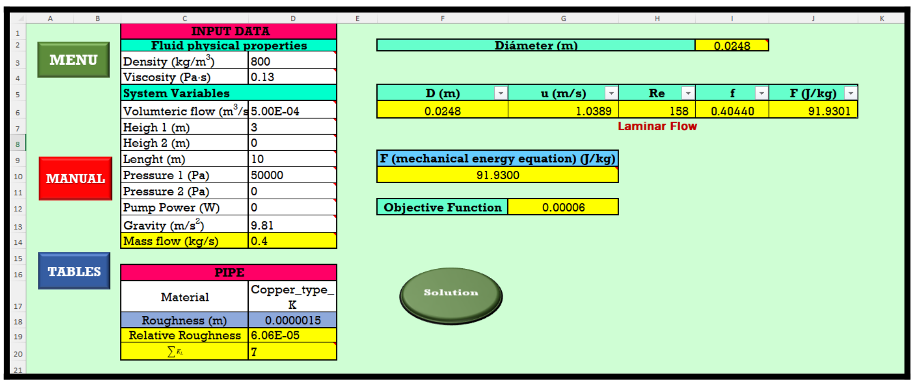

Figure 14. Calculations to solve Example 1.

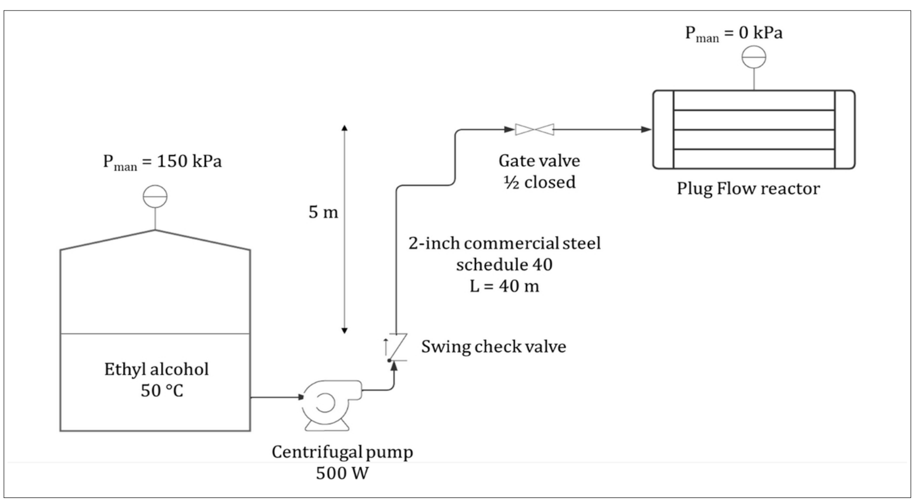

Figure 15. Flow diagram for Example 2.

Once all the values of the system variables have been entered, the spreadsheet finds the solution by pressing the "Solution" button which runs the macro to solve the problem as is shown in Figure 18.

The results obtained in the yellow cells are the following:

- Flow velocity: 4.6516 m/s
- Volumetric flow: 0.0101 m^3/s
- Mass flow: 7.8661 kg/s
- Reynolds Number: 272 120 (turbulent flow)
- Friction coefficient: 0.0150
- Friction losses in pipeline: 206.8216 J/kg
- Friction losses from the mechanic energy equation: 206.8217 J/kg
- Objective function: -0.00013

As a result, the flow velocity of ethyl alcohol is 4.6516 m/s.

INPUT DATA	
Fluid physical properties	
Density (kg/m^3)	780
Viscosity (Pa·s)	7.00E-04
System Variables	
Volumteric flow (m^3/s)	0.0101
Heigh 1 (m)	0
Heigh 2 (m)	5
Lenght (m)	40
Pressure 1 (Pa)	150000
Pressure 2 (Pa)	0
Pump Power (W)	500
Gravity (m/s^2)	9.81
Mass flow (kg/s)	7.8661

Figure 16. Input of system variables to solve Example 2.

Elbows		
Total	Elbow Type	K_L
4	Threaded	0.9
Valves		
Total	Valve Type	K_L
1	1/2 closed	2.1
1	Swing check valve	2
	-	0
	-	0

Figure 17. Selection of accessories to solve Example 2.

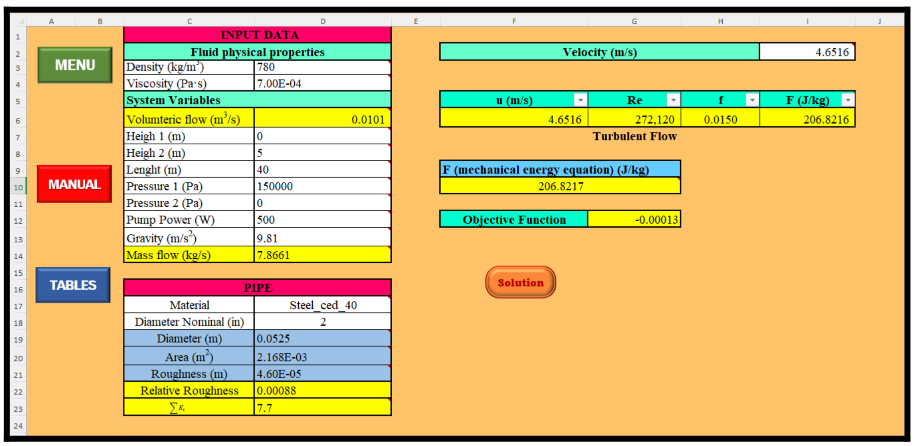

Figure 18. Calculations to solve Example 2.

Example 3. Pump's power calculation

A 20% NaCl solution is concentrated by pumping it through a cast iron pipe with a nominal diameter of 3 in and a flow rate of 0.0018 m^3/s from a storage tank that is exposed to the atmosphere to an evaporator that is situated 2 m above the level of the tank. The pipe system comprises a length of 5 m, two 90° flanged elbows, a swing check valve, and an angle valve that is fully open. The flow diagram in shown in Figure 19. The solution has a density of 1 150 kg/m^3 and a viscosity of 0.0014 Pa·s at the pumping temperature (30 °C). The evaporator operates at a vacuum pressure of 15 kPa. Calculate the pump's necessary power in W.

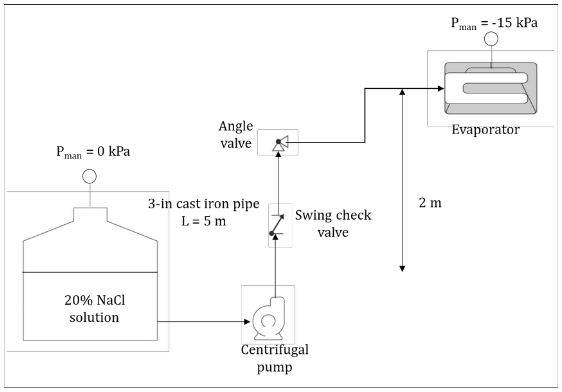

Figure 19. Flow diagram for Example 3.

Solution:

To solve the problem, the values of the physical properties of 20% NaCl solution at 30 °C are inserted in units of the international system: density in kg/m^3, and dynamic viscosity in Pa·s. Likewise, the system variables are also placed in the international system: volumetric flow rate (m^3/s), height 1 (m), height 2 (m), pipe length (m), pressure 1 (Pa), pressure 2 (Pa), gravity (m/s^2), pipe material and nominal diameter. Everything is done in the white cells of the spreadsheet designed as shown in Figure 20. Finally, in the Tables section, the types of accessories and their quantity are selected as indicated in Figure 21.

INPUT DATA	
Fluid physical properties	
Density (kg/m^3)	1150
Viscosity (Pa s)	1.400E-03
System Variables	
Volumetric flow (m^3/s)	0.0018
Heigh 1 (m)	0
Heigh 2 (m)	2
Lenght (m)	5
Pressure 1 (Pa)	0
Pressure 2 (Pa)	-15000
Gravity (m/s^2)	9.81
Mass flow (kg/s)	2.07

Figure 20. Input of system variables to solve Example 3.

Once all the values of the system variables have been entered, the spreadsheet automatically computes the power pump, in W, and displays it in a yellow cell as is shown in Figure 18. For this case of study, the power pump is 14.6249 W.

6. STUDENTS' PERCEPTIONS OF SPREADSHEET DEVELOPMENT FOR SOLVING FLUID FLOW PROBLEMS

Over several semesters, students have developed a project that involves creating an Excel program utilizing the spreadsheets described above. A survey was administered before and after the project to determine their perception of this activity. The results are described below.

Elbows		
Total	**Elbow Type**	**K_L**
2	Flanged	0.3
Valves		
Total	**Valve Type**	**K_L**
1	Angle valve, fully open	5
1	Swing check valve	2
	-	0
	-	0

Figure 21. Selection of accessories to solve Example 3.

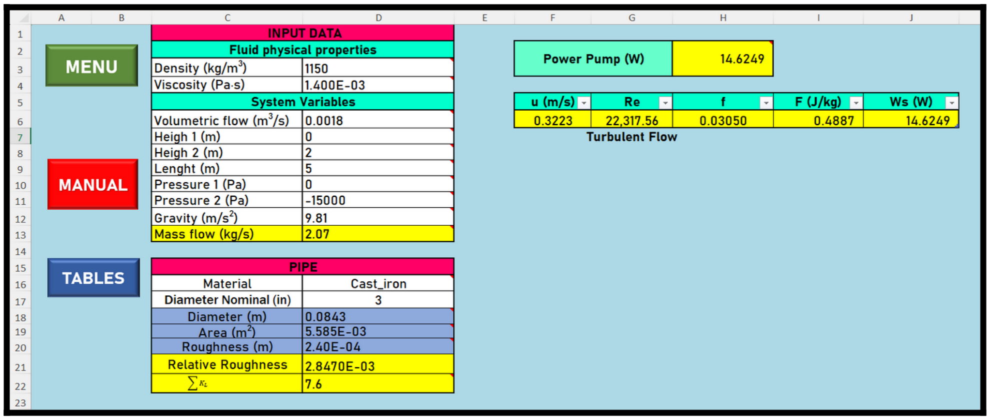

Figure 22. Calculations to solve Example 3.

Figure 23 shows students' perceptions of their level of knowledge about the mechanical energy equation and its application to fluid flow systems. Before completing the project, 71% considered themselves to have basic or no knowledge of this topic. However, after completing the project, the perception of knowledge about the mechanical energy equation increased considerably, reaching an intermediate and advanced level, with a total of 46%. Only 36% considered themselves to have basic knowledge, and the perception of having no understanding disappeared completely.

Further analysis of t he survey applied before the project, according to the results shown in Figure 24, 50% of students believe that developing the project could help them understand fluid mechanics; 43% are convinced that the project will definitely help them understand the fluid mechanics concepts presented; and only 7% do not consider it helpful in understanding these concepts. On the other hand, 29% of students believe they have no experience solving engineering problems using spreadsheets, 28% consider themselves to have only minor experience, and the rest have had experience solving engineering problems with spreadsheets.

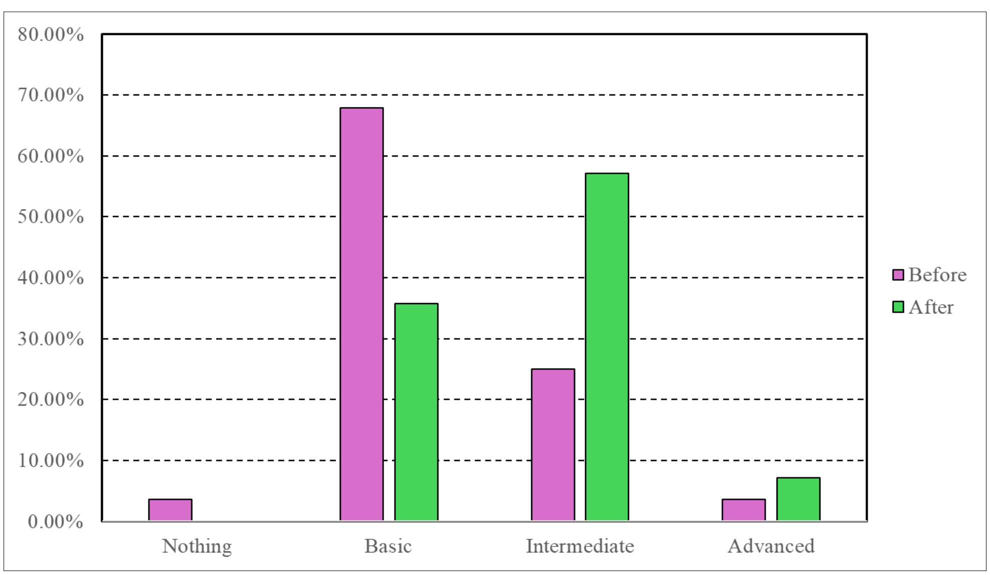

Figure 23. Student opinions regarding their knowledge of the mechanical energy equation and its application to fluid flow systems before and after completing the project.

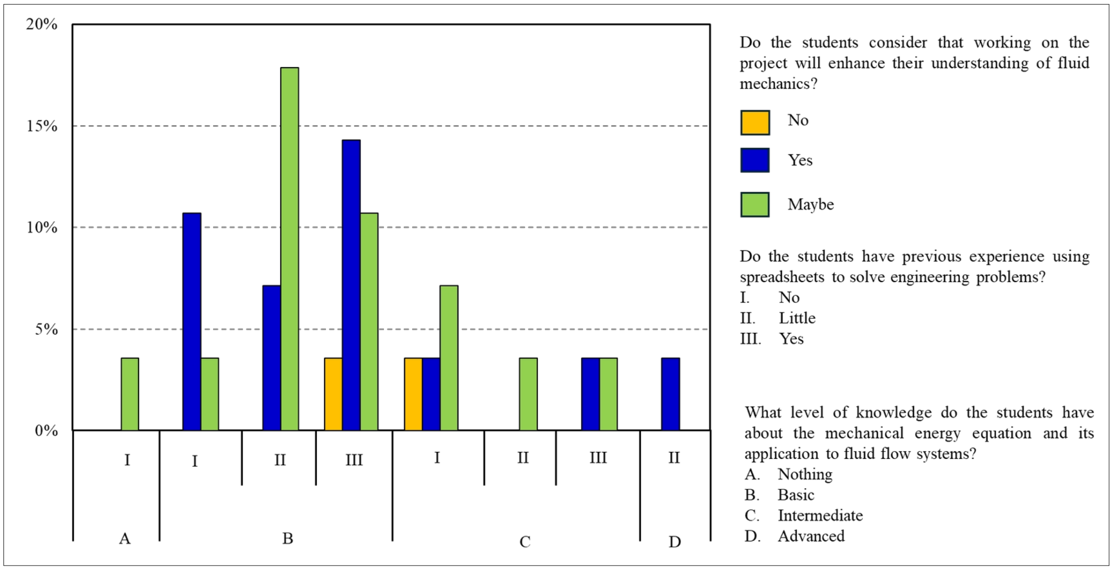

Figure 24. Opinion of the students before carrying out the project regarding their expectations of improving their understanding of fluid mechanics, experience in the use of spreadsheets to solve engineering problems, and their perception of the application of the mechanical energy equation in fluid flow systems.

As previously mentioned, before starting the project, most students considered themselves to have basic knowledge of applying the mechanical energy equation to fluid flow systems; however, students with experience using spreadsheets to solve engineering problems were convinced that executing the project would improve their understanding of fluid mechanics. This is interesting, since students' main fear in developing projects that enhance their technical knowledge may stem from their lack of skill in using computational tools rather than their understanding of basic engineering concepts.

After completing the project, students' perceptions changed dramatically, as shown in Figure 25. It is observed that 90% of students met their learning expectations, and 78% of them recommend the project to future students. It is also observed that the main difficulty experienced by students was related to technical problems (67%). This is mainly attributed to a lack of skill in organizing and programming spreadsheets. This provides an opportunity for other subjects to promote the use of spreadsheets in problem-solving, thus increasing students' proficiency in developing calculations and using applications integrated into commercial spreadsheets.

Students' perceptions regarding the use of spreadsheets for solving fluid flow problems are generally good, as shown in Figure 26. 73% of them consider that it makes problem-solving easier, but only slightly, while 15% believe it to be significantly easier, and 12% assume that it does not make it easier. This may be related to a lack of experience and skill in programming and designing the spreadsheet, despite considering themselves to have reached an intermediate level of knowledge in the use of the mechanical energy equation. Only 46% feel a slight improvement in the ease of solving fluid flow problems with the spreadsheet.

CONCLUSIONS

The utilization of ICT holds significant importance in the educational context of university engineering programs, as it plays a crucial role in preparing future engineers with the necessary skills and knowledge. The utilization of spreadsheets, particularly in Microsoft Excel, facilitates the comprehension and resolution of engineering

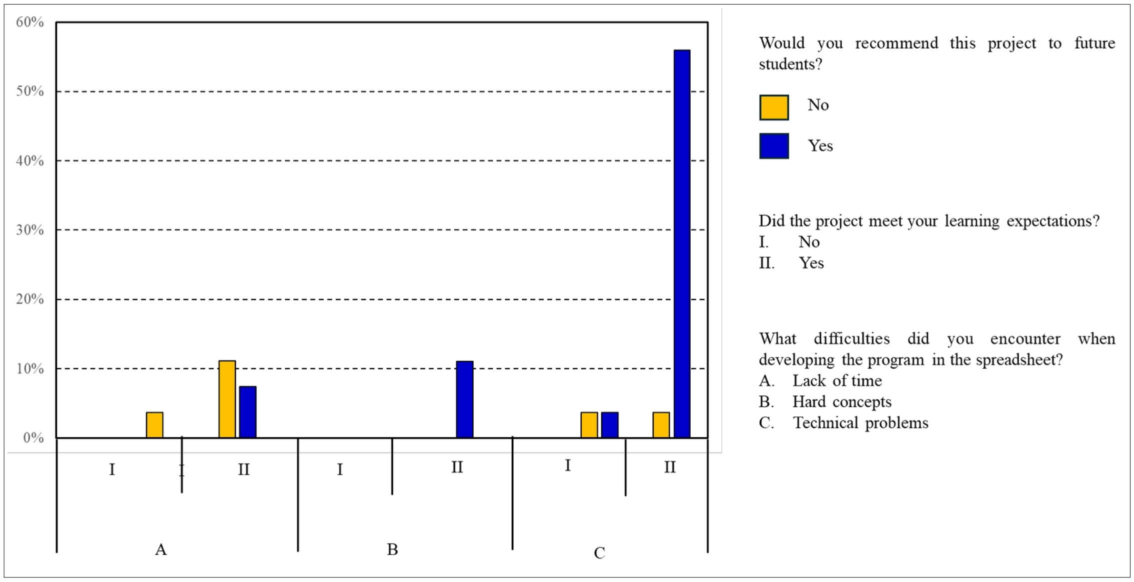

Figure 25. Opinion of the students after completing the project regarding whether they consider it recommendable for future students, whether it met their learning expectations, and the difficulties they encountered in developing the program.

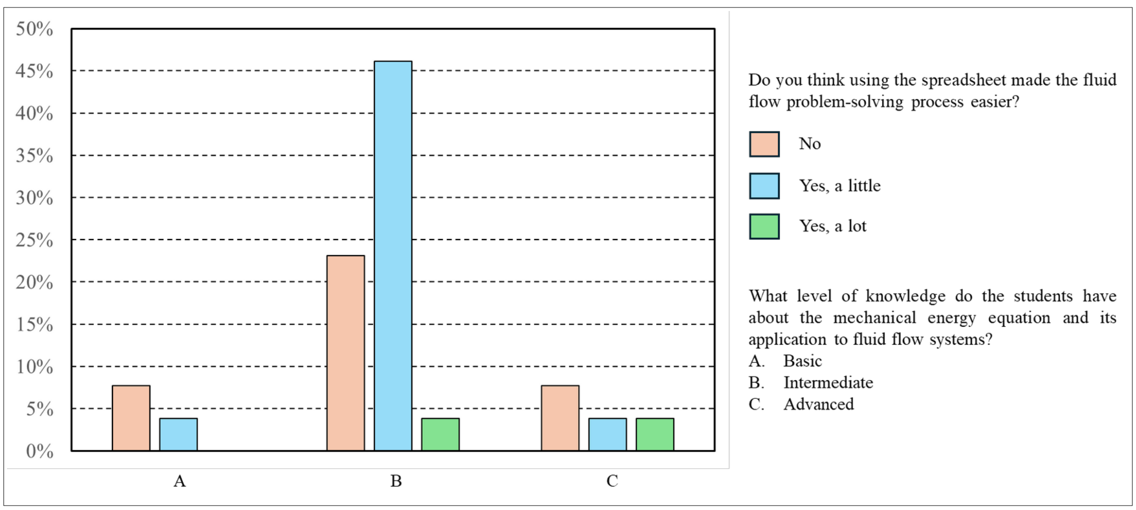

Figure 26. Students' opinions after completing the project regarding whether spreadsheets facilitate the resolution of fluid flow problems, and their knowledge of the mechanical energy equation and its application to fluid flow systems

problems at an intermediate level. This case study demonstrates the utilization of a spreadsheet equipped with a comprehensive and suitable database to simulate fluid behavior within a piping system for various characteristic scenarios commonly examined in academic settings.

These scenarios involve calculations related to fluid flow rate, pipe diameter, and pump power. In cases when the solution technique follows an iterative approach, the "GoalSeek" function, which is a component of the Microsoft Excel add-ins, executes a series of iterations until it successfully identifies the solution to the problem. However, it is very important to note that the provision of a suitable initial value is necessary for the function to operate effectively. Moreover, the implementation of a macro provides an organized strategy to address all the case studies presented in the manuscript. The students believe that completing the project enhanced their understanding of the application of mechanical energy in fluid flow systems and that the use of spreadsheets facilitates the solution of fluid flow problems. They also believe that the main difficulties in developing the spreadsheets are technical problems attributed to their lack of skill in using Microsoft Excel functions and applications. Nevertheless, their learning expectations have been met, and they recommend that the project be implemented in future classes. Given the aforementioned circumstances, it is imperative to emphasize the significance of acquiring proficiency and expertise in ICT for the training of prospective engineers. This is essential to ensure that, in conjunction with their hard and soft skills, they are able to effectively pursue their professional goals.

Acknowledgements

The authors would like to express their gratitude to all the college students from the institution for their invaluable participation in this project by using and suggesting improvements in the data sheets.

Availability of data and materials

The materials generated and/or analyzed during the current study are not publicly available due intellectual property but are available from the corresponding author on reasonable request.

Declarations Competing interests

The authors declare that they have no competing interests.

REFERENCES

[1] Adelana OP, Ishola AM. Assessment of teachers' awareness and proficiency in utilization of information and communication technology (ICT) packages in classroom instruction. *The African Journal of Behavioural and Scale Development Research* 2020; 2(2): 121–133. doi: 10.58579/AJB-SDR/2.2.2020.121.

[2] Salah B, Khan S, Ramadan M, Gjeldum N. Integrating the Concept of Industry 4.0 by Teaching Methodology in Industrial Engineering Curriculum. *Processes* 2020; 8(9): 1007. doi: 10.3390/pr8091007.

[3] Turaev U, Ostanov K, Abriyev N. Use of information and communication technologies in mathematics lessons as a means of students'creative thinking development. *Science and Innovation*. 2022, 1(A6), 437-447. doi: 10.5281/ZENODO.7179587.

[4] Edali M, Alaswad W, Bseibsu A, Sahem Z, Rajeb FB, Elkamel A. Chemical Engineering Graduate Courses Curriculum Development with Simulation Components. *Journal of Pure & Applied Sciences* 2021; 20(3): 64–73. doi: 10.51984/jopas.v20i3.1171.

[5] Ferreira EC, Lima R, Salcedo R. Spreadsheets in Chemical Engineering Education - A Tool in Process Design and Process Integration. *International Journal of Engineering Education* 2024; 20(6), 928-938. Disponible en: https://www.ijee.ie/articles/Vol20-6/IJEE1562.pdf.

[6] Andika R, Putra ZA. Teaching Programming to Chemical Engineering Students. *ASEAN Journal of Science and Engineering Education* 2021; 2(1): 51–60. doi: 10.17509/ajsee.v2i1.36935.

[7] Ford Versypt AN, Bara JE, Getman RB, Kieslich CA, Voronov RS. Apps for Chemical Engineering Education: Off the Shelf and Do It Yourself Development Options. *Chemical Engineering Education* 2020; 54(3). doi: 10.18260/2-1-370.660-116709.

[8] Briones L, Morales V, Iglesias J, Morales G, Escola JM. Application of the microsoft excel solver tool in the optimization of distillation sequences problems. *Computer Applications in Engineering Education* 2020; 28(2): 304–313. doi: 10.1002/cae.22193.

[9] Falconer J, Nicodemus G. Interactive Mathematica Simulations in Chemical Engineering Courses. *Chemical Engineering Education* 2014; 48(3): 165–174.

[10] Flagiello D, Parisi A, Lancia A, Di Natale F. A tool for mass transfer evaluation in packed-bed columns for chemical engineering students. *Education for Chemical Engineers* 2021; 37: 29–39. doi: 10.1016/j.ece.2021.08.001.

[11] Fricke A, Schoneberger, JC. Industrie 4.0 with MS-Excel? *Chemical Engineering Transactions* 2015; 43: 1303–1308. doi: 10.3303/CET1543218.

ACERCA DE LOS AUTORES

El Dr. Roberto Flores realizó sus estudios de licenciatura en Ingeniería Química Industrial y maestría en ciencias con Especialidad en Ingeniería Química en la Escuela Superior de Ingeniería Química e Industrias Extractivas del Instituto Politécnico Nacional. Sus estudios de doctorado en ciencias de ingeniería química los realizó en la Universidad de Texas A&M. Laboró en el Instituto de Investigaciones Eléctricas participando en proyectos para el control y reducción de la contaminación ambiental provocada durante la generación y transmisión de la energía eléctrica. Forma parte del Comité Académico del Ceneval para el examen de egreso de la licenciatura en Ingeniería Química. Actualmente es Profesor Investigador de Tiempo Completo de la Universidad Autónoma del Estado de Morelos y sus líneas de investigación están enfocadas en procesos para la remediación de la contaminación ambiental, desarrollo de habilidades y competencias verdes en procesos sustentables de ingeniería, y prácticas docentes para la enseñanza de Ingeniería en nivel universitario.

La Dra. Nadia Lara es profesora e investigadora en la Universidad Autónoma del Estado de Morelos (UAEM). Es doctora en Ingeniería y Ciencias Aplicadas con especialidad en Tecnología de Materiales, y cuenta con maestría y licenciatura en Ingeniería Industrial por la misma institución. Su investigación doctoral derivó en un prototipo innovador de cámara de crecimiento para plántulas de tomate, orientado a enfrentar retos agrícolas ante el cambio climático. Imparte cursos sobre inteligencia artificial aplicada al diseño instruccional, promoviendo el uso de tecnologías emergentes en la educación superior. Ha registrado solicitudes de patente y derechos de autor, demostrando su capacidad innovadora en los sectores agrícola y educativo. En 2023, recibió distinciones como “Mejor Profesora” y el “Premio al Mérito Académico”. Su trayectoria destaca por su compromiso con la sostenibilidad, la innovación científica y la formación de profesionales con visión de futuro.

La Dra. Silvia Mendoza Vergara, realizó sus estudios de licenciatura en Ciencias de la Educación, en el Instituto de Ciencias de la Educación de la Universidad Autónoma del Estado de Morelos. Sus estudios de doctorado en Innovación y Administración Educativa los cuales realizó en el Centro Universitario de Ciencias e Investigación. Laboró en el Instituto Mexicano de Tecnología del Agua, participando en proyectos de capacitación en el sector hidráulico nacional y en el desarrollo e implementación de la maestría y doctorado en Ciencias del Agua. Forma parte del Sistema de Evaluación y Acreditación de la Educación Superior. Actualmente esa Directora de Nivel Medio Superior de la Universidad Autónoma del Estado de Morelos.

El Dr. Rogelio Sotelo Boyás es Ingeniero Químico Petrolero por el IPN, y Doctor en Ciencias en Ingeniería Química por la Universidad de Texas A&M. Es miembro del sistema nacional de investigadores Nivel I. Sus líneas de investigación son tecnología de biomasa, diseño y optimización de procesos petroquímicos y modelado de reactores. Ha sido Director del Centro Mexicano para la Producción más Limpia, Jefe de la Sección de Posgrado e Investigación de la ESIQIE, Coordinador de la Red de Energía del IPN y representante del IPN en PEMEX. Ha ganado el premio por el mejor desempeño en Investigación de Tecnología de Biomasa por parte del AIST de Japón, premio a la Investigación del IPN en Desarrollo Tecnológico 2021, y el primer lugar en el concurso Sustainable Aviation Fuels 2023. Actualmente labora como profesor investigador en el IPN y es consultor para el desarrollo de proyectos relacionados con hidrógeno verde, bioetanol y bioturbosina.