Development of the Consumption Journey Tool to Improve Awareness and Critical Thinking on Sustainability in Engineering Students

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***Abstract*— This innovation to practice full paper presents the Consumption Journey Tool for sustainability awareness. Sustainability and environmental issues are current topics that industries, governments, and academia have studied and embraced. It is known that depletion, scarcity, pollution, and global warming are latent threats to human activities as we know them. As a challenge, academic institutions have been including sustainability topics in their curricula through elective courses, project-based activities, and course modules. Commonly, these approaches aim to create more conscious thinking about and efficient use of resources, savings, environmental impact, lifecycle analysis, and the design and re-design of products or services with reduced resource consumption and higher sustainability performance. The existing approaches considering sustainability focus primarily on the external perspective through the lifecycle of the products, ignoring the internal habits of the consumers. They do not include an analysis of individual consumption. However, it is critical to understand individual behaviors and how those behaviors influence the decision-making process of the designers. This paper describes a practical tool developed to improve engineering students' sensitivity and critical thinking about their environmental impact in daily activities. The instrument is named the Consumption Journey Tool, and it is based on the Design Thinking framework. The tool was introduced in an elective course of Industrial Ecology for four-year engineering students. The authors developed and used an assessment instrument to evaluate the students' perceptions of sustainability issues before and after the Consumption Journey Tool implementation. The initial assessment shows students demonstrated higher engagement and self-consciousness about their impact on resources after using the tool.**

Keywords—sustainability, consumption, student, engineering, behavior

I. INTRODUCTION

Resource depletion is one of the most critical issues in sustainability for future generations. This issue affects industrial, domestic, and human activities at all levels [1], [2]. Although consumers know the importance of environmental issues, they may not necessarily grasp the complexity of associated problems and impacts in the mid and long term [3]. Even with the information available in recent years, consumers are not opting for more environmentally friendly habits. Therefore, there is a need for awareness about the role that each citizen and society, in general, have in the solution of the environmental crisis [4]. Considering that feelings, way of thinking, and actions impact both sustainability and the ideation process, the academia should educate future engineers to identify, measure, and reflect on their environmental impact to propose solutions or interventions to mitigate such impact positively.

From the perspective of engineering education, academic institutions, in general, has the responsibility of creating consciousness, awareness, and critical thinking in future engineering students to incorporate sustainability issues in any engineering project or position in industrial and research duties [5], [6], [7]. In addition, it is noticeable that the professional market demands engineers with skills strictly related to sustainability like self-knowledge, strategy, critical thinking, systemic thinking, and integrated resolution of problems [8].

This article aims to contribute to the generation and promotion of awareness about sustainability issues through a design thinking-based tool, which provides a personal analysis of consumption patterns and proposes interventions to reduce the consumption of resources. The instrument is denominated the Consumption Journey and combines procedures of Journey Map and Service Blueprint tools to measure and analyze: consumption impacts during stages in a conventional journey scenario, critical stages of the journey scenario, costs associated with each journey stage, potential interventions to reduce or eliminate consumption items, and the possibility of reflecting about personal consumption patterns. The tool was designed to

provide and generate information related to the identification of situations/tasks involving the consumption of resources (water, energy and materials); the inventory of consumption during a typical 24-hour day of the life of students; and highlights on critical consumption activities and the potential of reduction through Circular Economy strategies like refuse, reduce, reuse and recycling. The tool will allow students to realize which activities demand higher resources. Besides, it will also permit students to determine the positive impact of implementing tasks to reduce and improve their consumption footprint. The main research question addressed in this article is: How can awareness of consumption habits be generated in engineering students?

In the following sections, this article explains the method used to develop the tool and describes the four stages of the Consumption Journey tool. Then, the paper presents a case study to illustrate the use of the instrument, a summary of the findings after its implementation, some discussions, and conclusions.

II. METHOD

The general methodology of this study is described as follows: the development of the proposal of consumption journey tool, the implementation of the consumption journey tool to a group of engineering students, the collection and analysis of data for both diagnostic and improvement scenarios.

Design thinking was employed as the main framework to generate the proposed tool since it enables creativity, system thinking, decision making, iterative and problem-solving oriented [9]. A four-step process was performed to generate the tool: i) review of design thinking tools; ii) selection of potential tools related to awareness, user's feelings and decision making; iii) inclusion of sustainability-awareness tasks, iv) and testing (through a case study). Each phase is described in detail as follows.

Steps i) and ii): after reviewing the list of Design Thinking tools provided by The Design Thinking Toolbox [10]) and analyzing the objectives and methodologies of the different instruments, three of them were selected considering a user-aware approach, and the analysis of situations based on scenarios composed of different stages and focused on the user. Those tools are Stakeholder Map, Customer Journey, and Service Blueprint. All those tools allow involving self-knowledge, visualizing the user's evolution in a scenario, and providing insights and useful data for subsequent decision-making.

Step iii) sustainability awareness is included taking the core approach of customer journey and service blueprint. But, instead of collecting data for customer (student) interactions, satisfaction, target achievement, or efficiency, the objective was to identify interactions with resource consumption points or moments along the journey (activity). To consolidate this, it is required to identify consumption-related products, devices, appliances, or services (energy, water, materials, others); and to select technical indicators to measure quantitative values for all of them in each stage of the journey.

Step iv) a preliminary test of the consumption journey was conducted with one student to identify possible weak points in terms of methodology, data collection, and considerations during the implementation of the proposed approach. Finally, the tool is settled by considering four stages or main tasks that include a final reflection about the exercise of measuring and improving the own consumption patterns.

The consumption journey is conceived following a problem-based learning, which has demonstrated to be a useful tool to include sustainability in engineering students [9], [10], but it has even more impact since students work on their own data and behavior, which is key to generate awareness and self-knowledge about their consumption patterns.

III. THE CONSUMPTION JOURNEY

The consumption journey consists of four main stages: Definition of the journey scenario, selection of indicators, journey diagnostic, and analysis of potential impact reductions. Each one of these stages is described in detail as follows:

A. Definition of the journey scenario

The first step is to identify the most suitable scenario to measure consumption impact. Therefore, the scenario must provide enough easiness to identify and measure consumption values and represent a daily-based activity to generate self-awareness in students. Here, it is recommendable to select journey scenarios comprised of several stages to compare and illustrate the different consumption behaviors across a routine based on several tasks. (i.e., a conventional day of university, routine during weekends, road trips, holidays, etc.). The journey scenario must meet three characteristics: i) measurable, which implies that data for measuring indicators can be collected from primary or secondary sources (i.e., electricity or water bills); ii) convertible to money, which means that data can be converted into financial values to have an economic value of each impact; and iii) scalable, which means that the journey can be considered in a daily, monthly or yearly basis to compare impacts in both short and long terms..

B. Selection of Indicators

Consumption patterns need to be measured in each task or activity of the journey scenario. Thus, it is necessary to identify and select the most suitable and practical consumption indicators that are involved during the diagnostic and analysis of potential impact reduction. Three key indicators can be easily used that provide measurability, convertibility to money, and scalability:

- Energy consumption (kWh) can be obtained from the power specification of each electrical, electronic, or mechanical device. In addition, its unit cost ($/kWh) can be obtained from the electricity bill. Other energy consumptions costs can be obtained from secondary sources (internet or previous literature) when fossil fuels are employed.
- Water consumption (m3) can be measured from the consumption specification of hydraulic devices or through indirect sources (i.e., the internet), which already have average water consumption values for any device. Similarly, its unit cost ($/m3) can also be obtained from

the water bill. Here, it is essential to clarify that other water consumptions can have different unit costs since water quality and specification are different according to the specific use (i.e., drinking vs. non-drinking water.)

- Material consumption (kg) can be measured from the consumption of consumables during the stages of the journey scenario. This indicator includes consumables related to cleaning and washing tasks, food, and other materials consumed during daily-basis activities.

C. *Journey Diagnostic*

Once the journey scenario and the indicators are selected, it is possible to perform the diagnosis of the journey. In this stage, students must consolidate a summary of consumption for each stage of the journey scenario in terms of the indicators previously selected. Here, students must summarize all products, devices, and appliances involved during their journey scenario (i.e., electronic, electrical, mechanical devices or situations where consumptions related to the indicators predefined are involved). Values for indicators in each stage of the journey scenario can be consolidated in a data sheet for further diagramming and analysis. The diagnostic could include economic impact as an additional data output if unit cost values for selected indicators are available. This diagnostic followed a survey approach to identify the degree of self-knowledge using a 1 to 10 scale.

D. *Analysis of potential impact reductions*

With the consolidation of consumption impacts through the whole journey scenario, it is possible to propose small interventions that can significantly reduce consumption impacts in months and years. At this point, students must identify the most impactful stages in their journey scenario and seek non-drastic interventions to reduce such impact. From a radical perspective, students can be asked to reduce at minimum impacts associated with their consumption patterns. From a more-flexible point of view, students can be asked to reduce consumption levels by implementing three or five interventions. Even only implementing one intervention on the highest impactful stage, students can evidence the reduction of consumption and therefore cost associated with it.

IV. CASE STUDY: A CONVENTIONAL DAY OF UNIVERSITY

To demonstrate the implementation and analysis of consumer behavior of students, a consumption journey was developed for a conventional day of university. Eleven students in the fourth year of industrial engineering from the elective course "Industrial Ecology" were chosen to perform the consumption journey using their own experience and consumption patterns. Students have previous knowledge about sustainability issues, circular economy, materials, chemistry, and physics. The socio-economic condition of all students corresponds to mid-high income in the Colombian context.

Before developing the consumption journey, several questions were performed to measure the awareness and degree of knowledge about their consumption patterns during a conventional day of university. Two questions were proposed at this point. Q1: What is the degree of self-knowledge about your consumption patterns during a traditional day of university? Q2: What is the consumption value for energy, water, and materials during a traditional day of university? Fig 1. shows the results for question 1, and Table I summarizes the results for question 2. Results for question 2 are listed in Table I. Surveys were developed using an online form and data was summarized in quantitative values and (No-response NR).

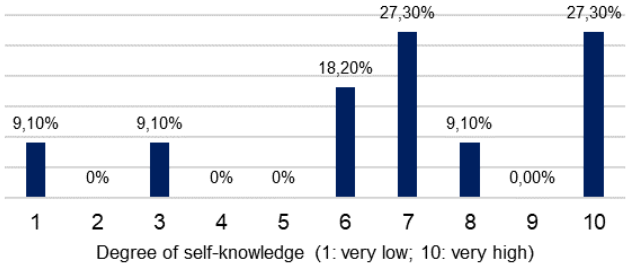

Fig. 1. Results of the degree of self-knowledge about consumption patterns in students (Question 1).

TABLE I: SELF-PERCEIVED CONSUMPTION VALUES OF STUDENTS IN TERMS OF ENERGY, WATER, AND MATERIALS

Student	*Energy (kWh)*	*Water (m^3)*	*Materials (kg)*
S1	NR	NR	NR
S2	NR	NR	NR
S3	NR	0,01	10
S4	NR	0,025	NR
S5	NR	0,005	NR
S6	NR	0,005	NR
S7	NR	NR	200
S8	NR	0,006	NR
S9	NR	0,004	NR
S10	NR	NR	NR
S11	NR	NR	NR

A. *Definition of the journey scenario*

The journey scenario consisted of a conventional day of university considering ten stages: 1) Wake up / Shower, 2) Breakfast, 3) Commute (home to campus), 4) Study, 5) Lunch, 6) Study, 7) Commute (campus to home), 8) Dinner, 9) Other activities, 10) Sleep. This journey scenario represents 20 days during a month and eight months during a year (two semesters).

B. *Selection of Indicators*

For the selected journey scenario, students were encouraged to measure consumption impact using three indicators: energy, water, and materials consumed during a conventional day of university.

C. *Journey Diagnostic*

The students developed the journey scenario diagnostic using the previously mentioned indicators. Then, data were collected and plotted. Fig. 2 shows a photo of students during the self-diagnostic task, while Fig. 3 shows the individual values for the 11 students for each indicator and the average values of each indicator considering all students. Data for each stage was collected, tabulated, and plotted using linear graphs

to compare consumption values and explore the evolution of values during the chosen scenario.

Fig 2. Students developing the Consumption Journey self-diagnostic for consumption of energy, water, and materials.

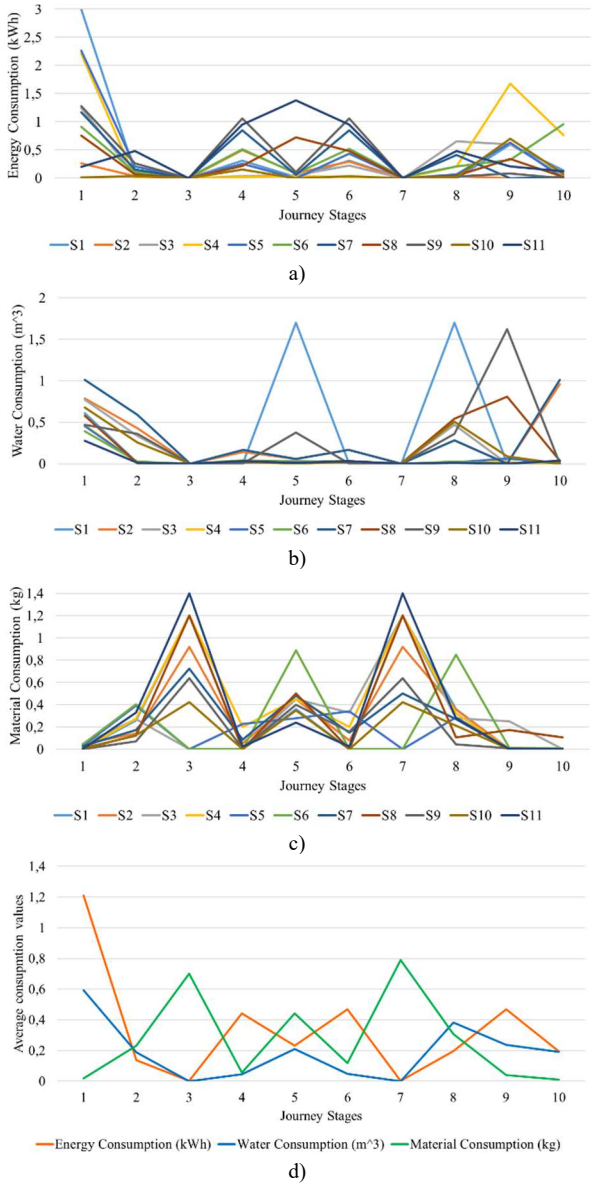

Fig 3. Summary of consumptions for 11 students. a) energy consumption in kWh, b) water consumption (m^3), c) material consumption (kg), and d) Average values

D. Analysis of potential impact reductions

Once the diagnostic is done, students can identify the stages of the journey scenario most suitable for interventions to reduce consumption values (for energy, water, and materials). At this point, students were asked to implement five interventions oriented to reducing consumption values throughout the journey scenario. For this case study, most students were focused on four main types of interventions: i) reducing time using energy-related products and water consumption devices; ii) eliminating the use of products not strictly necessary; iii) replacing the transportation means (home-campus-home) for other with lower energy consumption (i.e., bicycle instead of a personal car); and iv) eliminating not strictly necessary material consumptions (fast food, brunches, additional fat meals during the day). Fig. 4 shows the graphical comparison of consumption values once the improvement interventions are applied. Table II summarizes the cost reduction (average) after the implementation of the interventions proposed by the students.

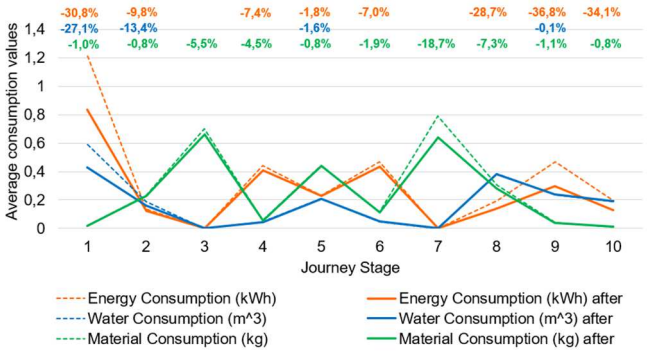

Fig 4. Comparison of average consumption values before and after implementing the interventions for reducing consumption patterns

TABLE II. SUMMARY OF COST REDUCTION (ANNUAL PROJECTION) PER STUDENT AFTER APPLYING INTERVENTIONS TO REDUCE ENERGY CONSUMPTION, WATER, AND MATERIALS.

Student	Daily Cost (USD)	Annual Costs (USD)	Annual Costs post (USD)	reduction
S1	4,56	730,34	693,42	-5.1%
S2	9,08	1452,14	1411,13	-2,8%
S3	12,11	1937,83	1002,43	-48,3%
S4	11,33	1812,70	1794,55	-1,0%
S5	3,70	591,76	515,99	-12,8%
S6	14,57	2331,13	2216,10	-4,9%
S7	11,13	1780,70	1680,71	-5,6%
S8	7,59	1213,83	1201,29	-1,0%
S9	13,63	2181,51	2139,48	-1,9%
S10	7,63	1221,27	909,10	-25,6%
S11	5,47	875,87	764,31	-12,7%

After implementing the interventions for reducing energy consumption, water, and material, students are encouraged to reflect on the activity and write down their findings and toughs. Here are some of the student's comments:

S2: "*The greatest changes in terms of costs can be seen in the first scenario, in which different values of energy use are altered. Several factors need to be changed to notice a difference in cost savings. It is necessary to make possible modifications when carrying them out. We cannot eliminate all the consumption of materials because most of them are vital for us, and the use of water, which we can greatly reduce, as this is largely wasted.*"

S4: "By analyzing personal daily consumption, one becomes aware of the impact it generates both economically and environmentally on the planet. Through small actions, it is possible to make a change, and if we dedicated many people to reducing our habits, it could improve the quality of life and preserve the renewable resources that we badly need. Although it may not seem like a significant change at first glance, it is possible to say that such simple changes positively impact both the personal economy and the environment. If one person makes these changes, it may not have the desired result, but if you run campaigns with data on how these changes would positively impact the planet, it would be possible to improve the quality of life for everyone and the planet."

S6: "Based on the interventions, it is possible to identify the significant impact that even the most negligible activity can generate. Specifically, I noticed that eliminating the consumption of elements that are not strictly necessary (such as beauty products and disposables) generates a considerable contribution to the reduction of materials and energy, which is something that could be easily implemented. In addition to the above, reusing materials (such as rainwater) is also something that does not require much effort and can have a significant impact on reducing the use of water, energy, materials, and waste generation. These changes can lead us to be more friendly to the environment and considerably reduce economic impact since."

S11: "As we can see, the changes made are not difficult or unusual to affect our quality of life. However, you can already see how a few simple changes reduce our cost of energy, water, and materials and how this reflected in a year is quite a lot of money. Therefore, if each person made these changes, they could save money and help reduce the consumption of these three pillars, which is why we as leaders must motivate and help more people understand the impact of excessive use of resources."

A single case, the Consumption Journey of student #10 (S10), is shown as follows to demonstrate the implementation of the consumption journey in a detailed case (one student). Table III shows the list of products, devices, and items related to each journey scenario stage for student S10.

TABLE III. LIST OF PRODUCTS, DEVICES, AND ITEMS RELATED TO EACH JOURNEY SCENARIO STAGE FOR STUDENT S10.

JOURNEY SCENARIO STAGE	***PRODUCTS, DEVICES AND ITEMS RELATED TO***		
	Energy	***Water***	***Materials***
1 Wake up / Shower	Lights (bathroom and room)	Shower Brush teeth Flush the toilet	Soap, toothpaste Shampoo
2 Breakfast	Microwave Light	Wash dishes and hands	Eggs, bread, milk, coffee, soap
3 Transport	-	-	Fuel
4 Study	Laptop and phone charge	Flush the toilet and wash hands	Soap
5 Lunch	-	-	Protein, rice, salad
6 Study	Lights	Flush the toilet	Soap
7 Transport	-	-	Fuel
8 Dinner	Lights	Wash dishes Brush teeth	Bread, cheese, fruit, ham
9 Other	TV and PS4	Drink water Wash hands Flush the toilet	Soap
10 Sleep	Lights Phone charge	-	-

Table IV presents the summary of energy, water, and materials consumption for student S10. Fig 5. plots the corresponding consumption of energy, water, and materials for all journey scenario stages. Table V and Fig. 6 describe the interventions proposed by student S10 and the percentual reductions for each journey stage after implementing the proposed interventions.

TABLE IV. DAILY ENERGY, WATER AND MATERIAL CONSUMPTIONS RELATED TO EACH JOURNEY SCENARIO STAGE FOR STUDENT #10 (S10).

Journey Scenario	**Energy (kWh)**	**Water (m^3)**	**Materials (kg)**
1 Wake up / Shower	0,012	0,677	0,001
2 Breakfast	0,039	0,258	0,124
3 Transport	0,000	0,000	0,425
4 Study	0,156	0,033	0,001
5 Lunch	0,000	0,000	0,350
6 Study	0,036	0,033	0,001
7 Transport	0,000	0,000	0,425
8 Dinner	0,021	0,507	0,210
9 Other	0,700	0,091	0,001
10 Sleep	0,072	0,00	0,000
TOTAL	**1,036**	**1,599**	**1,546**

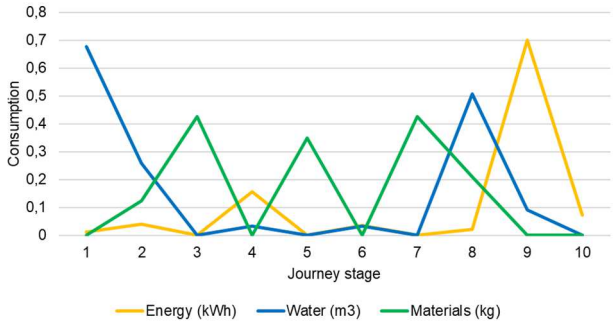

Fig 5. Summary of diagnostic consumption values for student S10

TABLE V. LIST OF INTERVENTIONS PROPOSED BY STUDENT #10 (S10) AND THE DAILY AND ANNUAL IMPACT OF EACH INTERVENTION.

Intervention proposed	***Daily impact***	***Annual impact***
Use bicycle instead of personal car or bus for transportation (home-campus-home)	-2,40kg of fuel (-1,509 USD)	-384kg of fuel (-241,44 USD)
Limit the use of the mobile phone to promote only one charge per day	-0,006 kWh (-0,0001 USD)	-0,96 kWh (-0,016 USD)
Eliminate the use of videogames (PS4) after arriving to home	-1 kWh (-0,167 USD)	-160 kWh (-26,72 USD)
Reduce time during the shower (eight minutes instead of ten)	-0.113 m^3 of water (-0.065 USD)	-18.08m^3 of water (-10.4 USD)
Eliminate the consumption of bread during the day	-0,02kg of bread (-0,21 USD)	-3,2 kg of bread (-33.6 USD)

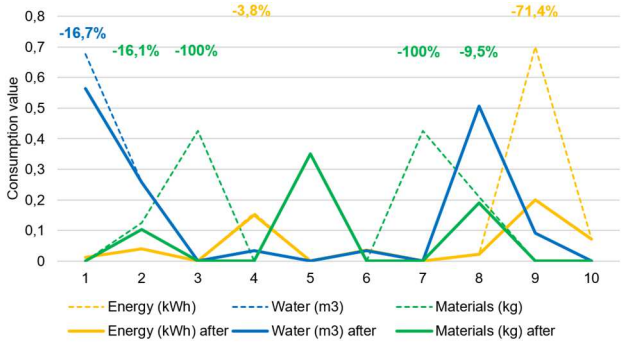

Fig 6. Summary of consumption reduction values for student #10 (S10) after implementing the five interventions

Final comment from student #10 (S10):

" Personally, the impact on the costs that surprised me the most was that of interventions 4 and 5, since in 4, simply reducing the time in the shower by two minutes, the decrease in the annual cost was considerable. In turn, in intervention 5, which consists of eliminating bread from the daily diet, the impact on costs was also important. This is something that can be applied since bread does not represent an essential source of nutrients in a person's daily diet. Finally, the greatest impact on costs was obtained in intervention 1, which involves getting around by bicycle. This would be ideal if implemented by a greater number of people to save a good sum of money annually and help reduce the polluting effects of getting around in a conventional car, bus, or motorcycle."

VI. Findings and Discussion

After the implementation of the Consumption Journey Tool, the following findings can be remarked:

- Regarding the research question, the Consumption Journey Tool represents a "how" approach to identifying and improving consumption patterns through a simple four-step process following single tasks with accessible data for engineering students. Students were capable of discovering and working on the improvement potential of consumption scenarios. Using their data involves a significant engagement of students according to the final comments obtained at the end of the study.
- Self-knowledge about consumption patterns seems to be relatively high for the students previously to the case study development. However, in the reflection statement, it was possible to establish that most of them did not know the impact of their consumption of resources.
- Students were not aware of their consumption patterns before implementing the consumption journey. Just half of them (6/11) declared a quantitative value for its consumption in terms of water. It was difficult for them to establish or guess a value for materials (2/11), and no one mentioned a value for energy (0/11).
- The methodology proposed provided a homogeneous tool to compare consumption patterns among the students. After reviewing the data, the consumption behavior trend is similar for energy, water, and materials.
- Students were capable of measuring, identifying critical consumption stages, and proposing interventions to reduce or eliminate consumption of resources in terms of indicators.
- Reductions in terms of cost varied from 1% to 48%. Therefore, the tool has prominent usefulness to compare and reduce values of resource consumption. More reductions are possible if students apply more drastic interventions. The use of cost helped to understand and demonstrate the impact of conventional activities.

The use of the consumption journey tool in the case study provides good ideas for the inclusion of sustainability issues in engineering education. The tool validates several students' skills, such as process assessment, use of indicators, identification of critical consumption points, and the ability to process interventions to mitigate impacts in the analyzed scenario, as well as the prediction of the reduction of impacts in the medium and long-term.

The consumption journey was developed to be independently performed by last year's students, which have a broader perspective of engineering tools and more analytical experience obtained from previous courses. However, the tool can be developed in students from the first to the third year also, including more accompanying activities to ensure they can satisfactorily finish the diagnostic and improvement of their consumption scenario. The design thinking approach facilitates the engagement of students with sustainability topics, especially since they are encouraged to work using their own data and experience. The consumption journey allows students to work on their creativity, intuition, story-based situations, solution-focused problems, and finally, focusing on how things ought to be versus how things are.

After reviewing the final results and feedback from students, it is clear that the tool can facilitate self-awareness and conscious thinking and trigger emotional feelings from students around the concept of sustainability. For the students, the use of data and experiences from their own lives represented an interesting approach to self-analysis and allowed them to measure their impacts on sustainability issues. Even minimal modifications allowed significant impacts in a month or a year. Thus, students realize that they are responsible (in large part) for the depletion of resources, which is one of the most critical environmental problems today.

The consumption journey tool was developed to follow a very simple and objective process to identify consumption values and implement little modifications to reduce consumption patterns in daily activities. The required data is found in the energy specification and the consumption values per unit of time of the devices or appliances. Therefore, the tool can be applied in developing and developed countries without significant limitations. It is important to clarify that some differences can be found in the unit values of energy, water, and materials depending on the socioeconomic context and the subsidy policies of the country. In such a case, it would be necessary to carry out a clustering process to separate and analyze the results.

VII. Conclusions

This article proposed a tool to improve awareness and critical thinking in engineering students around consumption behavior related to energy, water, and material resources. The consumption journey tool is described and implemented through a case study using a conventional day in the university as the journey scenario.

The main findings lie in students' lack of self-awareness and knowledge about their impacts on resource consumption. Students can have a vague idea about their consumption in terms of quantitative measures. However, there is a gap between managing common indicators like energy, water, and material consumption for engineering problems and their consumption pattern. On the other hand, using the consumption journey tool provided the opportunity to identify consumption patterns, stages, or tasks with higher consumption values; propose simple

interventions to mitigate or reduce consumption; reflect on their consumption; and develop more awareness about their responsibility as consumers. The student's final comments demonstrated that the consumption journey allows critical thinking, awareness, and actions around sustainability issues. The consumption journey was designed for engineering students; however, it can be expanded to other disciplines and collaborators in any industry or field when it is necessary to generate consciousness about consumption impacts.

The Consumption Journey tool is presented as a single answer to the research question posed in this work. Several features of the tool can be highlighted to ensure student awareness: i) the use of their data on consumption patterns, ii) data visualization and comparison of consumption values at different times around a specific situation, iii) related requirements identify how and how much can be reduced in terms of consumption impacts for each student according to their consumption journey.

As future challenges, it is required to acquire specialized data about processes, environmental indicators, values of consumption, chemical reactions, and other variables in the case of using the consumption journey to industrial activities. Thus, other versions of the consumption journey might be developed to address those scenarios. In addition, more quantitative analysis can be implemented to reduce subjectivity, i.e., in the case of student feedback and measurement of self-awareness.

ACKNOWLEDGMENTS

The authors would like to acknowledge the Engineering Technology and Commonwealth Engineering (ETCE) office at Penn State University, PA, USA.

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