Evaluating Learning Outcomes Through Curriculum Analytics: Actionable Insights for Curriculum Decision-making

A Design-based research approach to assess learning outcomes in higher education

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Abstract

Learning analytics (LA) emerged with the promise of improving student learning outcomes (LOs), however, its effectiveness in informing actionable insights remains a challenge. Curriculum analytics (CA), a subfield of LA, seeks to address this by using data to inform curriculum development. This study explores using CA to evaluate LOs through direct standardized measures at the subject level, examining how this process informs curriculum decision-making. Conducted at an engineering-focused higher education institution, the research involved 32 administrators and 153 faculty members, serving 9.906 students across nine programs. By utilizing the Integrative Learning Design Framework, we conducted three phases of this framework and present key results. Findings confirm the importance of stakeholder involvement throughout different design phases, highlighting the need for ongoing training and support. Among the actionable insights that emerged from LOs assessments, we identified faculty reflections regarding the need to incorporate active learning strategies, improve course planning, and acknowledge the need for education-specific training for faculty development. Although the study does not demonstrate whether these insights lead to improvements in LOs, this paper contributes to the CA field by offering a practical approach to evaluating LOs and translating these assessments into actionable improvements within an actual-world educational context.

CCS Concepts

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **HCI design and evaluation methods**;

Keywords

Additional Keywords and PhrasesLearning analytics, Curriculum analytics, Learning outcomes assessment, Actionable insights

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1 Introduction

Learning Analytics (LA) has emerged as a promising approach to enhance educational processes. LA is defined as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" [35]. Since its emergence, researchers have highlighted potential benefits associated with LA, including the improvement of student learning experiences and learning outcomes (LOs) [1, 41], by providing educators with evidence to inform their teaching [27].

However, translating data-driven insights into concrete learning improvement has proven elusive. This unfulfilled promise has led to a growing concern about the gap between LA's initial goals and its actual impact on student outcomes [4, 29, 37]. In a systematic literature review developed by [37], 70% of analyzed papers did not present LO assessment or improvement strategies. Among the few studies examining how these systems contribute to LOs attainment, an even smaller percentage focuses on providing feedback to administrators and instructors. As shown in [37, 42], most of LA research has focused on data analysis, with a relative dearth of studies exploring translating these data-driven insights into continuous improvement. In fact, only 71.1% of LA-related work included any measure of LOs, and 89% of studies do not attempt to intervene in the learning environment [29].

This is particularly concerning given that LOs assessment is increasingly recognized as a critical component of continuous curriculum improvement in higher education. Continuous curriculum improvement involves systematically assessing student outcomes within specific courses to evaluate curriculum effectiveness [20]. Deriving insights from student LOs assessment could facilitate quality assurance [38], enhance transparency with society, and foster a comprehensive education that equips students with the skills

needed for succeeding in a dynamic job market, while also empowering them to contribute meaningfully to societal development [7, 31, 32]. In this context, curriculum analytics (CA), a subfield of LA focused on collecting, analyzing, and visualizing educational data, offers a promising approach to support LOs assessment and inform decision-making [17, 19]. Previous initiatives have studied using LA tools to support accreditation and continuous improvement processes [8, 22, 25]. Still, these studies primarily focused on collecting and visualizing data related to competencies or LOs for accreditation purposes, without delving deeply into the tools' impact on curriculum improvement, failing to demonstrate how LOs evaluation directly informs the development of improvement actions.

To fully realize CA's potential, exploring how these data are translated into actionable insights in authentic teaching contexts is necessary. By actionable insights, we mean information that an instructor or academic program "may or may not feel compelled to act upon" [23]. To close the loop between data analysis and the effects of improvement actions on learners 'experiences [9], CA tools should encompass all stages of design, from data generation to impact evaluation [16], ensuring data quality through valid and reliable LO-related construct measurement [13]. To advance in understanding of CA's impact on curriculum improvement, this paper presents a study that is part of a larger research project. This study was conducted in a higher education institution specializing in engineering and technology. Through a design-based research approach, this study aims to answer the following research questions: How can CA support the evaluation of LO attainment using direct standardized measures of subject-level assessment results? And how do these direct measures of LO attainment inform continuous curriculum improvement? Following the Integrative Learning Design Framework (IDL) [3], this paper presents the design, implementation, and impact evaluation of a process for assessing LOs through a CA tool and examines how this process informs the formulation of specific improvement actions.

2 Background

2.1 Challenges in learning outcomes assessment

In the field of LA, measuring LOs attainment has faced several challenges. The first major challenge in the literature is the lack of a clear and consistent definition of LOs. As shown in [4, 30] previous studies often employ the term "learning outcomes" without a theoretical definition. This ambiguity can hinder the development of effective interventions and assessments, limiting the ability to measure and evaluate student progress accurately. In this study, we define LOs as a set of knowledge, skills, and attitudes that students at a university community develop during their studies, extending beyond disciplinary boundaries [6, 7].

Another significant challenge in measuring LOs is the diversity of assessment approaches, which along with the lack of standardization in the concept of LOs and the diverse evaluation methods, complicate comparisons among programs or institutions. The primary methods for measuring LOs include course grades, indirect measures (which rely on student self-reports), and direct measures (where teachers assess student performance of academic evidence) [26]. Each of these assessment approaches has its own strengths and weaknesses, so there is no consensus on the measurement of this construct. Course grades can encompass a wide range of learning strategies and assessment activities, ranging from traditional educational formats to innovative educational strategies. Moreover, grades are the most common approach to assessment, which, despite their availability, suffer from a lack of standardization and primarily represent knowledge mastery, not practical skills [7, 43, 45]. Indirect self-report measures, while cost-effective, may have low validity due to the inherent bias of self-reported data, where subjects may tend to overestimate their abilities [10, 39]. Finally, direct assessments, where instructors measure skill mastery in authentic scenarios, can offer a more objective evaluation by providing large-scale comparability and reliable outcomes [26, 28].

In addition, direct assessment also prompts teachers to reflect on how to enhance the intended LOs in their courses. In the context of CA, the direct measurement of LOs also allows instructors to make their own observations and generate knowledge about how faculty think about their data as part of their daily work [5]. As reported by [40], instructors are particularly important as analytics users because they are involved in daily assessments of their students' progress to guide their teaching. This element should contribute to actionable insights at the subject level, reflecting on how they have taught the LO, how they have conducted the assessment, and how they can use the data to improve their students' learning [23].

3 Method

The research objective of this study is twofold. On the one hand, we explore how CA can support the evaluation of LO attainment using direct standardized measures of subject-level assessment results. On the other hand, we examine how these direct measures of LO attainment inform curriculum decision-making. To this end, an instrumental case study was conducted, delving into using direct LOs measurement through CA as actionable insight to instructors and faculty. We employed a design-based research approach in an actual-world university, using the Integrative Learning Design Framework (ILD) as a basis [3]. So far, previous research has already used this framework to guide the design and implementation of CA tools [17, 19].

In this study, the first three phases of the ILD framework were used to go beyond tool deployment and evaluate whether the tool usage served the formulation of continuous improvement actions. The ILD phases are the following:

- The Informed Exploration Phase: This phase identifies and defines the problem considering the educational needs of CA's intended users (i.e., academic administrators and faculty).
- Enactment: This phase proposes an initial design or prototype of the process and the supporting CA tool.
- Local Evaluation. This phase aims to evaluate the perceived usability and usefulness of the CA tool from the perspective of its intended users in the formulation of continuous improvement actions.
- Broader Evaluation: Finally, this phase evaluates the consequences of the adoption of the process and the CA tool to a wider audience.

Table 1: Sources of qualitative information for triangulation

Phase	Information sources	Study Objectives
Phase 1: The Informed Exploration Phase	-Document analysis (Minutes of program committees, accreditation agency guides, and institutional process documentation and presentations for faculty members (elaborated by the institutional academic advisors) -Semi-structured interview with an institutional administrator	-Understand what aspects were taken into consideration for the development of the LOs evaluation process as well as the CA tool
Phase 2: Enactment	-Semi-structured interviews with an institutional administrator -Semi-structured interviews with developers and designers of CA tool -Documentary analysis (articles published, methodological guide, memorandums, minutes, tutorials)	-Understand the process used for a) designing and validating the standardized scales, b) developing the methodology guide, c) designing and developing the CA tool -Understand the process used for developing the CA tool -Understand the process used for a) developing the methodology guide, b) developing the validation of the standardized scales, c) developing the CA tool
Phase 3: The Evaluation Phase	-Semi-structured interviews with an institutional administrator -Semi-structured interviews with five coordinators and instructors -Documentary analysis (a report summarizing improvement opportunities identified by faculty, and a memo detailing enhancement made to the CA tool based on a usability workshop as well as peer reviewer's feedback)	-Evaluate the perceived usability and usefulness of the CA tool from the perspective of institutional administrator -Evaluate the perceived usability and usefulness of the CA tool from the perspective of designers, developers, and instructors -Evaluate the perceived usability and usefulness of the CA tool from the perspective of instructors and for peer reviewers

In reporting the work developed for informed exploration, enactment, and local evaluation, different sources of information were triangulated to deepen our understanding of the processes and tools used to directly measure LOs attainment as actionable insights. By triangulation, we refer to the application of diverse data collection techniques, the collaboration of multiple researchers in the analysis process, and the integration of findings based on different sources to investigate a phenomenon from multiple perspectives [11]. In this study, findings are based on the qualitative sources of information described in Table 1. These sources were analyzed by a researcher involved in deploying the three phases previously described. Following the guidelines from [36], one researcher inductively coded various sources of information to identify key aspects for each phase, such as expectations related to the assessment process, the deployment of the CA tool, and the roles of different stakeholders. This involved assigning codes to relevant sentences or ideas within documents or interview transcriptions. Following the first round of coding, peer debriefing sessions were held between the researcher and another researcher to ensure coding validity. Subsequently, the researcher conducted a second round of analysis to group the initial codes into sub-themes, aiming to derive findings supported by multiple sources. Finally, these sub-themes were organized into broader themes, which were also reviewed by two researchers to ensure the validity and credibility of the qualitative analysis.

Concerning the context of this study, the research site is Instituto Tecnológico de Costa Rica, a Latin American university focused on engineering education. It was founded in 1971, and its current enrollment is of approximately 40,000 students served by 871 faculty members. Since 2014, the university has been trying to incorporate LOs evaluation as part of a self-assessment process for program accreditation and continuous curriculum improvement with the Canadian Engineering Accreditation Board (CAEB). In that year, the institution defined an initial strategy to carry out this process. In 2022 a process of redesigning the LOs evaluation procedure began for accreditation with a national accreditation agency known as AAPIA (Agencia de Acreditación de Programas de Ingeniería y de Arquitectura), incorporating lessons learned from the first version of the process. In doing so, a pre-existing module in the LMS was used to develop a CA tool. Our study is focused on the redesigning process, during which nine faculties were committed to certifying their quality with an accreditation agency whose focus is the evaluation of LOs for comprehensive education in engineering education. Approximately 9,906 students were enrolled in these 9 engineering programs, which were taught by 153 instructors. Considering that the broader evaluation phase implies evaluation adoption in a wider audience, this phase goes beyond the scope of this work. Still, the following sections illustrate how LOs have been assessed and used for continuous curriculum improvement in the context previously described, and future work has considered the implementation of a multiple case study to contrast this experience with the one of other institutions.

4 Results

In this section, we present each of the three first phases of this framework as a narrative report of its main results.

4.1 Informed exploration

In the exploration phase, a researcher, an engineering instructor, and an institutional administrator employed the analysis of three primary information sources. First, a literature review was conducted to examine existing approaches to measuring LOs in universities within the context of accreditation. This review focused on identifying best practices and potential challenges associated with LOs measurement for accreditation purposes. Second, insights from peer reviewers who participated in previous accreditation visits collected in feedback meetings were considered. Finally, official documents and guidelines from the accreditation agency itself, as well as previous institutional process documentation, were analyzed. To understand how the researcher, the engineering instructor, and the institutional administrator addressed the educational needs related to LOs assessment for accreditation in the institution, the authors of this study reviewed documents associated with the process, including minutes, presentations, and institutional documentation. This analysis was supplemented by an interview with an institutional administrator who participated in the process, providing insights into its development through her narrative.

Table 2 presents the main findings derived from triangulating these sources of information. This analysis revealed a convergence between the agency's requirements, peer evaluators' observations, and best practices identified in the literature. The three sources suggested that a stakeholder-driven process was essential for designing the CA tool and its successful implementation. This approach needed to be formalized in a guiding document that aligned with institutional regulations. A CA tool had to be developed to support this process, considering both the guiding document and user needs. By utilizing high-quality assessment instruments, the CA tool could enhance faculty understanding of their teaching practices and the program's and institution's knowledge of student LO progress. Still, it had to facilitate informed decision-making at both the course and institutional levels and streamline data collection, analysis, and visualization for students, instructors, and administrators. In doing so, the team of designers and programmers had to progressively develop the CA tool prototype, regularly receive user feedback, and iterate based on this feedback and design principles.

4.2 Enactment

The exploration phase revealed key findings to support the LOs evaluation process and the CA tool design. It specifically highlighted the need to develop high-quality assessment tools, create a guiding document for the process, and design the CA tool based on the guiding document and user needs. In this second phase, the main objectives were to: a) design and validate standardized scales to assess LOs through a pilot study; b) develop a preliminary process for evaluating LOs according to institutional regulations (and documented in a methodological guide); and c) create a prototype design of a CA tool based on the defined methodology.

4.2.1 Design and Validation of the Standardized Scales for Measuring LOs Through a Pilot Study. This process involved two stages. The first stage focused on designing indicators for the scales used to evaluate LOs. This stage included conducting 11 workshops with 27 experts in pedagogy, engineering, philosophy, and other fields related to the LOs developed in the nine engineering programs. After completing the workshops for designing the LO indicators, a peer review process was carried out with 27 different experts to ensure content validity. Fleiss' kappa was calculated to assess peer agreement as evidence of construct validity. In the second stage, a pilot study was conducted to evaluate the validity and reliability of the indicators. Faculty used these instruments to assess student evidence and determine achievement levels relative to course LOs. The database extracted from the LMS contained data from 1420 students evaluated by 64 instructors in 66 courses. This research provided evidence supporting the construct validity of the scales (findings are currently under review for publication). This process resulted in the development of 11 standardized scales, each with five performance levels: 1 = Does not meet the indicator, 2 = Achieves minimal compliance with the indicator, 3 = Meets the indicator but requires opportunities for improvement, 4 = Meets the indicator, 5 = Exceeds expectations in meeting the indicator (Figure 1).

4.2.2 Develop of a preliminary process for evaluating LOs. A methodological guide was developed by institutional academic advisors for assessing LOs according to institutional regulations [15], outlining a four-step process (mapping LOs in the curriculum, assessment of LOs, data analysis, and improvement plan). These four steps were implemented as follows: Mapping was conducted before the evaluation process, limiting the assessment to only one LO per course. Instructors collaboratively determined which LO could be assessed in each course of the curriculum grid, and the school council formally approved it. Then, the LOs were assessed by 153 faculty members in the LMS, using the standardized scales corresponding to the LO mapped to their respective courses to evaluate student evidence. The methodology encouraged teaching staff to design learning strategies with peers to observe the LO and to include them in the syllabus and instructional design, in which LO would be fostered and measured in the course. At the end of the semester, 32 accreditation coordinators followed up on the data analysis and prepared a report on the outcomes of the process. According to the guide, the academic program was required to design an improvement plan for courses where at least 75% of students did not meet the expected level of achievement (a score of 3 or higher on the evaluation scale). These plans were developed collaboratively by course instructors, the accreditation coordinator, and the program chair. The chair and accreditation coordinator presented the report with improvement actions to each school council.

According to institutional regulations, the institutional academic advising office had to coordinate this process in collaboration with the institutional accreditation committee. It was defined that academic advisors and program coordinators should collaborate to support instructors in evaluating LOs and planning improvement actions based on the data. Faculty, including the chair of each academic program and course instructors, were expected to actively participate in the process. During this period, academic advisors were to provide support to faculty on pedagogical matters as well

Table 2: Findings derived from the informed exploration phase regarding expectations for the LO assessment process

	Findings	Description	Source of information
	Clear definition of process and tools	Clearly define the evaluation process and assessment tools to ensure they meet the university's needs for accreditation and continuous improvement. While a general procedure for evaluating LOs should be established and approved by the highest academic authority of the vice-chancellorship of teaching, individual schools or programs should develop their own management guidelines within the framework of the institutional regulations. These guidelines should align with the institution's overall guide, while considering the unique context and culture of each program	Semi-structured interview with institutional administrator Presentation for faculty members
	Guiding document of the process aligned with institutional regulations	Outline a guiding document of the evaluation strategy, aligned with institutional regulations and university governance principles setting roles and responsibilities. This guide should include how to collect and analyze data for improving the learning process	Semi-structured interview with institutional administrator Presentation for faculty members
	Stakeholders' active involvement	Involve all stakeholders (instructors, authorities, and administrative staff) actively and collaboratively in the design process.	Semi-structured interview with institutional administrator
	High-quality assessment tools	Conduct a pilot study to identify validity and reliability indicators in the LOs assessment scales	Semi-structured interview with institutional administrator Presentation for faculty members
	Curriculum analytics tool design process	The team of designers and programmers will progressively develop the functionalities of the CA tool, regularly receiving feedback from users and iterating based on user feedback and design principles	Semi-structured interview with institutional administrator Minutes

as on the LOs assessment process. Based on this experience, the methodology guide was designed and led by the academic advising office and validated through a focus group involving 11 course instructors who coordinated the accreditation process in their respective faculties[14]. The guide was also reviewed and approved by the institutional teaching council.

4.2.3 Prototype design of a CA tool based on the defined methodology. The CA tool for measuring LOs was developed by the unit responsible for the institutional LMS (Learning Management System) [Demo at [2]]. A team comprised of two designers and one software developer gathered requirements from three key sources: the methodological guide, academic advisors overseeing the process, and faculty. This collaborative approach resulted in a system catering to two distinct user types: 1) Attributes Manager functionality, designed for program or school accreditation coordinators, who can map courses, monitor LOs evaluations across courses, and visualize results at the end of each cycle; 2) LMS Functionality, an integrated feature within the LMS that enables instructors to conduct LOs evaluations for their assigned courses within the evaluation section. The system visualizes results to highlight courses meeting methodology-defined parameters and identify those courses requiring improvement plans. From the perspective of designers and developers, the system was designed for expert users in the institutional process (Figure 3, Figure 4). The "Attributes Manager" role within the system provides graphical visualizations of overall LOs compliance, complemented by a breakdown of achievement for individual indicators for each LO. Moreover, it shows comments made by instructors during the assessment associated with the evidence. This comprehensive view facilitates informed decision-making regarding program improvement initiatives. The institutional unit

Indicators	Learning outcome: Communication	1	2	3	4	5
The student:						
Communicates engineering concepts and ideas effectively, both orally and in writing, while considering cultural, linguistic, and learning differences.						
Delivers clear and effective oral presentations on engineering and its social context, considering cultural, linguistic, and learning differences.						
Produces clear and effective written documents on engineering and its social context, considering cultural, linguistic, and learning differences.						
Develops clear and specific instructions for engineering tasks, considering cultural, linguistic, and learning differences within the broader societal context.						

Performance levels:

1= Does not meet the indicator	2= Meets minimum requirements for the indicator	3= Meets the indicator but requires improvement opportunities	4= Meets the indicator	5= Exceeds expectations for the indicator

Figure 1: Example of the scale for evaluating communication. Adapted from [15]

Figure 2: Methodology guide for evaluating learning outcomes. Adapted from [15]

responsible for this CA tool is currently designing a dashboard for instructors and students to visualize their results.

4.3 Evaluation of Local Impact

In this phase, we present the perceived usability and usefulness of the CA tool, as evaluated by its intended users, to inform continuous decision-making. Both interviews and documentation analysis revealed significant faculty participation in the evaluation of LOs using the CA tool as part of a continuous improvement process. A total of 132 instructors used the CA tool to assess the LOs of approximately 3,701 students.

Regarding the usability of the CA tool, the tool's alignment with the institutional framework, as confirmed by interviews, makes it an ideal fit for users familiar with the LOs assessment procedure:

> "The methodology is easy to follow and has good tables. The tool adapts to that process" (Course instructor)

> "The advantage we have is that the colleagues who developed the tool have worked shoulder to shoulder with us and the instructors and following the methodology (...) that has been a very strategic alliance." (Institutional administrator)

Additional to interviews, the documentary analysis allows the researchers to identify the multiple enhancements to the CA tool from user's feedback and evaluation experiences (Table 3). However, despite regular enhancements and support from developers and institutional administrators in using the CA tool and understanding the process, resistance in instructors to evaluate LOs through the CA tool persist:

Learning outcome	Course	Student	Excl.	Aprob.	Repro.	No Eval.	Evidenc.	$\bar{X}$	σ	% achievement	Improvement plan	Obs.	Graphics
DI (I)	1	26	0	6 (35%)	11 (65%)	9	9	2.57	0.08	35	Yes	70	
IN (I)	2	18	0	13 (76%)	4 (24%)	1	5	3.09	0.10	76	No		
AP (I)	3	9	0	5 (63%)	3 (38%)	1	4	3.00	0.03	63	No	40	

Figure 3: Outcomes visualization from the CA tool.

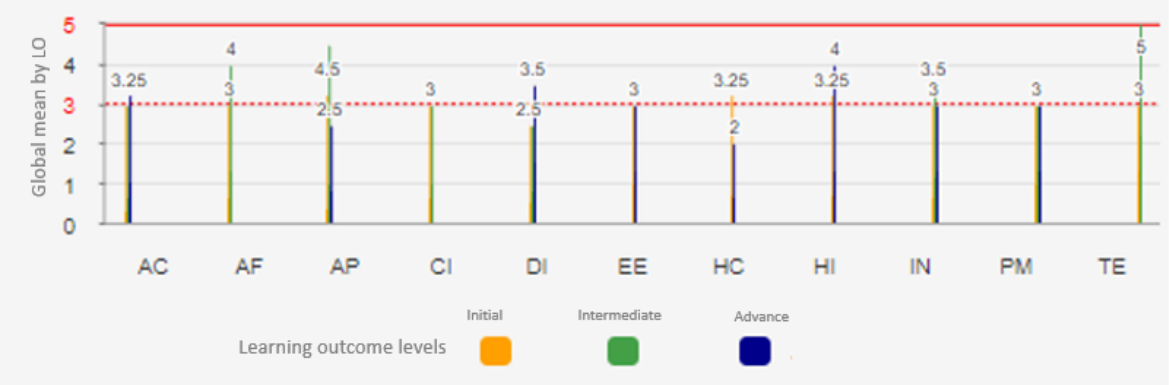

Figure 4: CA tool-generated visualization of average achievement levels for all assessed LOs within an academic program.

Table 3: Extracts from memo describing enhancements made to the CA tool according to users' feedback

Enhancement	Description of the enhancement
Definition of functions according to the process	There is an interface for each user (accreditation coordinators and instructors) Instructors carry out the LOs evaluation from their course portal
Data Visibility and accessibility	Access to overall results (including other support schools involved) Ease of downloading charts Overall performance chart and split by LO
Clarity and Organization	Clear and descriptive chart and data names: the title graphics accurately reflect the content being displayed Logical ordering of information: Arrange tabs and data in a sequence that is easy to follow and intuitive for users Consistency between screen and downloadable tables: Maintain the same order of data in both formats to avoid confusion
Improved Usability	Enhanced visibility of observations and comments: Make it easier for users to view and track their feedback Simplified user interface: The icons for downloading graphics are now more prominently displayed Contextual guidance: A shortcut to relevant pedagogical guidance material is available when completing the attribute evaluation scale
Performance and stability	Optimized response time: The tool responds more quickly, providing a smoother and faster user experience Resolved issues: bugs that caused unevaluated evidence to appear as zero and inconsistencies between displayed and downloadable information have been fixed
Customization and Flexibility	Flexible download formats: Users can select the data download format that best meets their requirements

> "Our school has faced significant resistance to the LMS. Some instructors were completely opposed to using it, even though the platform was available and improved. They continued to use excel for grading instead of the tool." (instructor)

> "At the end-of-semester the platform is slow and unreliable, so people are likely to be frustrated with it. If I try to introduce the CA tool in that moment, I know it's more likely to face resistance. If something goes wrong later, it could be used as an excuse to switch to a different platform, which would further hinder the process." (instructor)

According to the interviewed instructors the utility of CA-based LOs evaluation for continuous improvement yielded mixed results. Some schools viewed it as a mere accreditation formality, while others highly valued its contribution to learning enhancement. The analysis revealed that those who perceived the process as a formality for accreditation did not identify improvement actions. However, participants who worked in faculties that saw the process as a mechanism for improving teaching quality identified that the

Table 4: Improvement actions derived from direct LOs assessment with support of the CA tool

Faculty reflections categorization	Sample supporting quotes
Pedagogical innovation through active learning methodologies	"I find the evaluation of LOs useful because it encourages us to use active learning methodologies, and that improves students' learning (...) we consider that active methodologies do influence the significant learning of our population (...) So, I feel that, more so with accreditation, we have seen that this evaluation process is a general support to improve the ways in which a course is taught and evaluated" "Personally, I really like this methodology of learning by cases and projects because it encourages students to engage analytically and reflectively when faced with real situations (. . .) For example, I used a real case to address the topic of ethics in engineering (. . .) Although this is just my example, we have primarily seen improvements in how we evaluate and teach (. . .) I am confident that these improvements will continue to grow over time (. . .) we are making progress little by little"
Course planning improvement	"Among the improvement actions of this process is that it has also led us to improve the course descriptions and the entire operational part. Now the courses have better instructions, clearer procedures, clearer schedules" "The instructions for the assessment activities are getting better and better, although there is still a long way to go, we have been improving"
Fostering comprehensive education	"This process leads us as teachers to go "a little further", showing students how to develop skills such as teamwork or communication skills, in hard science courses. We have seen how this improves student motivation towards those skills, we see students more engaged (. . .) and that motivates us too" "In this institutional process of evaluating LOs, students have been the last to be involved. First, it started with the teachers. The incorporation of a visualization tool for students would allow the students to see that there are other important aspects of the evaluation beyond the contents of the courses and to show the importance of reinforcing those skills for their professional future"
Request for teacher training	"Some programs have request training courses to support the assessment of soft skills". "As a result of this process, we identified a need for training in education"

LOs evaluation process and data analysis led to an increase in the use of active learning methodologies to enhance student engagement and LOs, clearer learning instructions, and more effective evaluation strategies, as well as better instructional designs. Some academic programs also identified the need for training in pedagogical mediation skills and support in addressing challenges related to faculty's ability to foster professional skills such as teamwork and communication. Therefore, they sought support from the academic advisor office and implemented tailored training courses, promoting teaching skills in faculty (Table 4). In addition, one academic program has started conducting educational research to improve professional skills in the curriculum:

> "We are doing research for strengthen LOs (. . .) we hope to gain insights that will elevate our teaching methods and create a more effective learning environment." (program coordinator)

As a result of identifying areas of improvement from the assessment process and data analysis, instructors identified an increase in student motivation when professional skills were integrated into technical courses. For this reason, they emphasized the importance of involving students more actively and having them track their progress in the CA tool to increase their motivation.

Our analysis suggests that academic programs that place a high value on LOs assessment for curriculum decision-making are more likely to implement improvement actions. Factors that may influence faculty involvement include perceived workload, the need for more support in understanding the process, and the need to improve the usability of the CA tool. Despite the perceived usefulness and curriculum improvement initiatives, there is a consensus that the process requires further maturation. This suggests that its benefits may increase over time with a deeper understanding of the process. Additionally, instructors and administrators agreed that the identified improvement actions remain relatively conservative as the process is still in its early stages.

5 Discussion and lessons learned

This paper offers a valuable contribution to the field of learning analytics by demonstrating a practical approach to evaluate learning outcomes through standardized scales using a curriculum analytics tool, engaging stakeholders in different design stages, and employing valid and reliable metrics in a real-life context. Through the IDL framework, our study explores how these metrics can be effectively translated into actionable insights for curriculum improvement

initiatives, contributing to bridging the gap between LA's initial goals and student outcomes.

Our exploration phase led to a roadmap for the design process, which included an institutional guide, a pilot study to identify valid and reliable assessment indicators, and the design of the CA tool based on the first two steps. A key lesson learned is that close collaboration with stakeholders is crucial for understanding how the CA tool can support continuous improvement. These results confirm the findings of [9, 16, 17], which emphasize the importance of incorporating stakeholders' perspectives to understand the interplay between the teaching-learning process and practical and technical constraints when designing, implementing. and evaluating CA tools. Thus, CA design processes should prioritize stakeholder engagement while aligning with institutional governance and regulations.

The enactment phase yielded an initial design of a methodological guide describing the LO evaluation process, a set of standardized scales with robust evidence of validity and reliability, and a CA tool aligned with the procedure and scales. Ongoing consultation, training, and support for instructors and managers were provided to ensure proficiency in the LOs process and the adoption of the CA tool for mapping, evaluation, and data visualization. Besides, the standardized scales allow the comparison of LOs achievement through time. A key lesson learned is that, given the dynamic nature of educational contexts and the importance of continuously assessing stakeholder needs, the CA tool requires regular updates to adapt to evolving university trends and realities. This finding agrees with those found by [18].

In the local impact evaluation phase, we found that the CA tool was broadly used by faculty, however, while the tool has undergone several enhancements based on user feedback, instructor resistance to its use persists. In addition, the CA tool effectiveness in promoting continuous improvement actions varied across programs. Our content analysis suggests that the main factor influencing the generation of improvement actions is the value that the faculty places on the development of these LOs within the curriculum as part of comprehensive engineering education. In programs where no improvement actions were detected, the LOs assessment process was perceived as a task that increases workload and a formality for accreditation. This finding aligns with previous research, which indicates that actionable insights are influenced by personal values and other contextual factors not fully accounted for the analysis [23]. The phenomenon of how LOs evaluation processes for accreditation can lead to higher perceived workload and resistance among faculty has also been widely studied. Previous research has also identified potential strategies to address this challenge, such as clear procedures, stakeholder engagement, a standardized approach across the institution, standardized assessment tools, templates, regular support, and technological tools to facilitate assessment and data visualization [12, 14, 21, 24, 33, 34, 44]. The design process reported in this publication aligned with these recommendations; however, our findings suggest that additional strategies are needed to effectively support faculty in these processes.

Thus, it is important to foster awareness among faculty regarding the significance of LOs teaching and assessment to their students' professional development. In addition, regular training is needed for the successful implementation of the CA tool and support to explore how to use its data to improve the learning process [16, 17]. According to [40], rethinking LA design in the context of instructional practices demands ways to help instructors translate analytic information into actionable insights for their teaching; in doing so, they must see analytics as a bridge to overcome key teaching obstacles for successful adoption. Among the improvement actions detected in this study, we identified an increase in the implementation of active learning strategies, improved planning and assessments, a willingness among instructors to develop mediation strategies for comprehensive education, and specific requests for training to improve teaching skills (particularly professional skills). In these lines, some authors claimed that users involved in daily assessment of their students could contribute to actionable insights in their courses, as they regularly reflect on how their teaching impacts their student learning [23, 40]. So, our final lesson learned is that, despite the use of standardized assessment tools in this case study to provide reliable data for decision-making [30], transforming data into actionable insights is a complex process that requires more than just valid and reliable measures. For impactful analytics adoption, faculty must perceive this new technology as directly addressing their key teaching challenges [40].

6 Conclusions and future work

Through a design-based research approach conducted in an actual university setting, this study contributes to the CA research field by providing a systematic process for measuring LOs using standardized, robust psychometric scales. Our findings also demonstrate how LO attainment results visualized through a CA tool can lead to curriculum improvement actions. Although our study does not demonstrate whether these insights lead to improvements in LOs, this paper contributes to the CA field by offering a practical approach to evaluating LOs and translating these evaluations into actionable insights within an actual-world educational context. By addressing the gap in research between the intended purposes of LA for learning improvement and its actual impact [4], this work contributes to a deeper understanding of LA's effectiveness in educational environments and actionable insights from LOs assessment [23].

We captured the following key lessons learned for successful CA tool implementation:

- Active stakeholder engagement: Open communication and collaboration with faculty, institutional administrators, coordinators, and other relevant stakeholders are crucial throughout the design, development, and evaluation process. By prioritizing stakeholder engagement, institutions can ensure alignment between the CA tool and their specific needs, facilitating meaningful improvements in teaching and learning.
- Ongoing training and support: Despite the benefits observed in continuous improvement by faculty, they also reported increased workload and resistance, a phenomenon noted in other studies. To address this challenge, instructors need ongoing training and support to develop a deep understanding of the processes involved in assessing LOs. Additionally, they require guidance on effectively utilizing the continuous assessment CA tools that facilitate this process.

- Reinforcing the value of comprehensive education: The incorporation of LOs in engineering curricula is essential for achieving quality education. By recognizing the value of comprehensive education, faculty and students can more fully leverage the potential of analytics tools to support teaching and learning.
- Transforming data into actionable insights is a complex process: To stimulate actionable insights from CA usage, valid and reliable assessment tools are necessary, along with an understanding of how the LOs assessment process and the CA tool directly address critical teaching challenges.

One limitation of this study is the short period of time analyzed, so the incidence of the CA tool in improvement actions is conservative. Further long-term studies are necessary to fully comprehend the implications of using CA tools for curriculum continuous improvement and its impact on LOs in diverse university settings. In future work, we will explore the fourth phase of the IDL approach (broader evaluation) to understand how CA has been implemented in different university settings and how it has impacted continuous improvement.

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