Automating Formative Assessment for STEM Courses in Hybrid Learning Environments

Hong Liu
Mathematics Department
Embry Riddle Aeronautical University
Daytona Beach, Florida, USA
hong.liu@erau.edu

Rob Chadwick
Veracity Learning
Gulf Breeze, Florida, USA
rob@veracity.it

Naomi Malone
Cybermedia Technologies
Reston, Virginia, USA
nmalone@ctec-corp.com

Jason Haag
Veracity Learning
Gulf Breeze, Florida, USA
jason@veracity.it

Clement Yedjou
Department of Agricultural Sciences
Florida Agricultural and Mechanical University
Tallahassee, Florida, USA
clement.yedjou@famu.edu

Mike Spector
University of North Texas
Denton, Texas, USA
Mike.Spector@unt.edu

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***Abstract*— This paper presents an innovative courseware project based on the Adaptive Distributed Learning (ADL) Initiative's Total Learning Architecture (TLA [1]), which encompasses a technical framework for education and training based on a data strategy built around open standards to support interoperability across diverse organizations and products ([2]). This framework includes definitions of a set of policies, specifications, and standards that enable a future learning ecosystem to facilitate lifelong learning principles promoting personalized and flexible learning environments that include both formal and informal activities [3]. In Fall 2023, a TLA-inspired course framework was implemented in a data visualization course for senior undergraduates and graduate students, using Moodle and a Learning Record Store (LRS) to track over 200,000 learning records. This system allowed instructors to visually monitor online learning activities for the whole class as well as selected individual learners. As future work, the course will expand to 10 STEM courses across 11 universities in the next three years as part of an existing NSF commitment.**

Keywords—Adaptive Distributive Learning, Learning Analytics, Hybrid Learning Environment, Instructional Design, STEM Education.

I. Introduction

In today's big data revolution, those who have the data analytics skills to derive actionable insight from big data are in high demand. The need for new graduates and professionals to upskill in data science (DS) exceeds the capacity of universities. To enhance DS educational opportunities, a group of 11 universities, including three where the co-authors are affiliated, have formed a coalition to offer DS courses, particularly to universities that serve underrepresented minority populations. These courses are delivered through a hybrid model, combining both in-person and online learning. This approach allowed students from all 11 universities to cross-enroll in up to 10 DS courses, providing access to resources that might otherwise be unavailable.

This work involves a long-term interinstitutional collaboration to offer DS courses sponsored by the USA National Science Foundation (NSF) in three phases. The early two phases of the hybrid DS courses, from 2013-2016 and 2017-2020, used distributed learning (DL) technologies to deliver the DS course to small classes of mixed remote and in-person students [4] [5]. The class sizes were typically 20 - 30 while only 5 -10 remote students took the courses through teleconferencing tools such as Zoom. In this third phase (2022-2025), we extended the partnership universities from 4 to 11 universities and DS courses from 5 to 10 courses. Such an extension brought two significant challenges: (a) the cross-campus enrolled students exhibit greater diversity in their academic backgrounds, and)b) class sizes have the potential to exceed 50 students.

The grounding research question is how to effectively use AI-based learning technologies to offer large-sized hybrid learning classes without compromising the learning outcomes and overloading instructors. This paper presents an innovative courseware project based on the Adaptive Distributed Learning (ADL) initiative 's Total Learning Architecture (TLA). TLA provides a technical framework for education and training based on a data strategy built around open standards to support interoperability across diverse organizations and products [2]. This framework includes definitions of a set of policies, specifications, and standards that enable a future learning ecosystem to facilitate lifelong learning principles promoting personalized and flexible learning environments that include both formal and informal activities [3].

In Fall 2023, the TLA-inspired framework was successfully implemented in a data visualization course for 32 senior undergraduates and graduate students at the authors' universities. Though the course was offered as a traditional class lecture course in Fall 2023, it was developed as a hybrid learning course, allowing students from the other 10 universities to take it at their own pace, using either synchronous or asynchronous learning (http://icycle.cloud). On average, there were 5 students chosen to take the course through Zoom synchronously and sometimes asynchronously due to off-campus internships and sports or conference events.

The framework utilized the learning management system Moodle and a database-backed system called a Learning Record Store (LRS), which gathered over 200,000 learning records from these students in one semester. This system made the students' online learning activities visible to instructors through visual learning analytics.

This paper has seven sections. Besides this introduction as the first section, the second section reviews literature on ADL and learning analytics, emphasizing personalized learning. The third section outlines the course design, aligning objectives, activities, and assessments. The fourth describes ADL implementation, detailing data exchange between Moodle,LRS and cloud deployment of learning management systems. The fifth section examines learning records, providing feedback to instructors and students through a graph-based dashboard and visual analytics. The sixth compares ADL and traditional courses, evaluating ADL's effectiveness. The seventh summarizes findings, discusses challenges and expansion plans, and reflects on ADL's impact in post-secondary education. While the other 9 courses will subsequently adopt ADL, all 10 courses feature competency-based assessments, incorporate research components, and offer follow-up summer research opportunities.

We anticipate that our primary audience will consist of STEM (Science, Technologies, Engineering, and Mathematics) educators, learning scientists, and educational technologists. In section 4, we will focus on basic technology integration configurations, opting not to delve into the intricacies of system customization and extension. This approach is intended to assist educational technologists and Learning Management System (LMS) developers. Readers who are not looking to develop a data-driven ADL course may skip section 4 without impacting their overall comprehension.

II. THEORENTICAL BACKGROUND AND LITERATURE REVIEW

This section also provides an overview of the ADL technologies developed by the U.S. Department of Defense (DoD), underscoring the pivotal role of cross-platform data exchange technologies in enabling automated formative assessments and immediate feedback. The difference between DL (distributed learning) and ADL courses is that the latter follows the IEEE data interoperability standards (IEEE 9274.1.1) to leverage the power of AI (artificial intelligence), big data, and communication technologies to provide learning that can be personalized and delivered anytime and anywhere to almost any individual student. Through the rigorous collection and assessment of student data, ADL systems, such as the one proposed herein, can establish robust feedback mechanisms that aid both students and instructors, enhance course quality by tailoring content and assessments, and contribute to a deeper comprehension of human learning processes [6].

A. Interoperable Learning Data Exchange Technologies and Databases

Experience Application Program Interface (xAPI) statements are data generated by a Learner Record Provider (LRP) and sent to a special database called a Learning Record Store (LRS). The LRP can be a LMS such as Moodle or Canvas but can also be any website wherein learning activities occurs. This technology aims to enable the recording of learning activities wherever they take place, with the capability to use learning analytics for assessing learning outcomes from the xAPI records in the Learning Record Store (LRS) either in real-time or at a later time. We will use the xAPI interoperable data format to track and record student learning activities in Moodle. An xAPI assertion, using Javascript Object Notation (JSON), can be mapped onto a uniform "who did what" format with a time stamp and optional auxiliaries. Once a student completes a tagged task, such as a homework assignment or quiz, a record in xAPI will be saved in an LRS, thereby providing LMSs such as Moodle or Intelligent Tutoring Systems like the Generalized Intelligence Framework for Tutoring (GIFT) with the information necessary to tailor course content to individual students [7][8]. For instance, in the xAPI assertion "Susan completed Data Science Ethics (Novice)", the subject "Susan" refers to a specific student. However, the verb "did" must be replaced by a particular verb from the glossary of the unambiguous words whose semantics are predefined (e.g., 'completed') by the project team. The underscored object "what" links to the predefined knowledge, skills, task, or content with clear learning objectives. The auxiliary segment is used to determine competency level: Novice, Intermediate, or Expert. As structured textual data in JSON format with predefined vocabulary, xAPI assertions are not only interoperable, but also can quickly be processed and "understood" by computers.

An xAPI assertion supports variable granularities to assess multiple levels of nested competencies that are stored in a chain of Noise LRS, Transactional LRS, and Authoritative LRS. For example, the low level of event such as "Susan viewed a video clip" is stored in a noised LRS of LMS, while a high level of competency such as the following completion note "Susan asserted Data Visualization course (A)" is stored in an authoritative LRS of an enterprise registration system. Learning activities at all levels of granularity offer substantial evidence for assessing learning outcomes and evaluating progress. It is important to note that xAPI and LRS are all pervasive learning technologies sponsored by the Advanced Distributed Learning Initiative that can help build universal learner profiles to track learners of all ages and encourage lifelong learning [3]. As shown in section 4 with details, such a cloud-based LMS and databases allowed instructors to visually monitor online learning activities for the whole class as well as selected individual learner.

B. Selecting Compatible LMS and Course Authoring Tools and Technology Integration

More and more learning platforms and educational tools are starting to use the xAPI data format, which is now an approved IEEE standard (IEEE 9274.1.1). However, it is important to note that integrating these technologies into various LMSs and online course creation systems may require varying levels of effort due to differences in their current state of compatibility. We selected Moodle and GIFT as our LMS and Articulate 360 Storyline as our course authoring tools. We found that these tools are all xAPI compatible, requiring minimal effort to configure the plug-and-play subsystems to let data flow between the LRP and LRS. The GIFT (Authors 2022, http://3.12.146.191:8080/dashboard/#login), Moodle learning website (https://icycle.cloud), and the Veracity LRS database (https://erau.xapi.io) were all deployed on AWS Cloud services.

C. Competency-Based Assessment

Our research approach is rooted in competency-based assessment (CBA) and ongoing learning analytics, as described by [9]. Learning analytics, as defined by Siemens & Gašević [10] and Gašević, Dawson, & Siemens ([11] p.1), involves gathering, measuring, analyzing, and reporting data on learners and their environments to better understand and enhance learning. We want to emphasize that we have found that promoting learner collaboration boosts student motivation and performance. In our previous two phases of the foundation projects, we have implemented new strategies to foster collaborative learning among students through team efforts and provide prompt feedback during problem-solving tasks [12]. The xAPI statements collected for teamwork activities of this course made the individual and team performances transparent to the instructor and teammates at the first time (see section 5).

III. COMPTENTECY-BASED INSTRUCTIONAL DESIGN

To optimize inclusive active learning to support diverse students from different universities, we will apply CBA to identify effective practices. These practices can align instructional design with the appropriate delivery modality. The ADL course was designed to cater to both in-person and online students, supporting hybrid delivery. For remote learners, virtual community interactions complement classroom relationships, and synthetic environments enhance real-world learning experiences. Although our past DL courses focused on active and constructive learning based on Chi's iCAP taxonomy for deep understanding, traditional memorization techniques are sometimes necessary [13]. Our instructional design will consider three key elements: (a) content types (Facts, Procedures, Concepts, Principles, Processes [14]), (b) their cognitive load, delivery modes, and (c) students' cognitive traits, competencies, and prerequisites. The diverse delivery modes and student backgrounds present a challenge in designing DL courses, making a universal solution impractical. Individual student differences make a difference in instruction and assessment. As a major goal of the third phase project, we will use CBA to identify the most effective current practices for each course, allow peers to replicate these methods, and assess their effectiveness and areas for improvement.

A. *Competency Frameworks*

For the specifics of the data visualization course design, we aligned the learning objectives, activities, and assessment components to ensure a cohesive educational experience to fulfill the targeted competencies. First, we designed a DS competency framework by tailoring and extending existing ones [15][16]. Building this framework enabled us to design individual competency taxonomies and team competency taxonomies.

B. *Align Competency Objectives, Learning Activities, and Learning Assessments*

The three top level competencies to evaluate if a student has completed the Data Visualization Courses successfully are:

- Competencies to Prepare Data (CPD): Identify relevant data sources, retrieve data, cleanse data, transform data, and warehouse data for research problems under concern.
- Competencies to Explore Data (CED): Use Python or R data visualization libraries and a commercial tool to conduct visual data analytics and identify plausible models for further quantitative analysis.
- Competencies to Explain Findings (CEF): Apply visualization principles, tools, and DS ethics to communicate effectively for diverse audiences.

C. *Three Tiers of Course Organization Structure*

The course consists of three tiers: the top tier consists of six modules, each module comprising of up to 7 lessons for an overall total of 32 lessons with each lesson featuring two to three learning activities along with corresponding assessments. Each lesson consists of a video or text introduction, the first set of slides, a multiple-choice quiz, the second set of slides, a True-False quiz, a summary, and finally references with links for further reading and practice.

Shown in Table 1, each lesson is comprised of 3 to 4 learning activities, focusing on different knowledge types: factual, conceptual, procedural, principal, or process [14]. The instructional design tailors learning activities and assessments to these knowledge types. For instance, factual and conceptual knowledge are taught through traditional lecture notes, like PowerPoint slides, and assessed with quizzes (multiple choice or true/false). This segmented approach aids in gradual learning and testing, especially effective in asynchronous modes, keeping students motivated. Procedural knowledge is conveyed through online tutorials and reinforced through homework exercises. Principal knowledge is taught using video clips, lecture notes, and case studies, with understanding assessed through proctored exams. Process knowledge is developed through team projects, with weekly feedback from instructors. Table 1 illustrates the learning objectives of each module and how these objective summed up to achieve the three top level competencies.

TABLE I. ALIGNMENT OF COMPETENCIES TO MODULE OBJECTIVES

Module	Three Competency Hierarchy		
	Course Level	*Module Level*	*Lesson Level*
Module 1	CEF	Principles & Tableau 7 Lessons	Data types, Tufte's Visual Excellencies, Gestalt's Psychophysics, Cognitive Issues, and Tableau to design dashboard
Module 2	CPD	Data Preparation 6 Lessons	Set up Python, NumPy, and Jupyter Notebook Environment and Use Pandas to cleanse, reshape, aggregate, and transform data
Module 3	CED	Data-task taxonomy 5 Lessons	Schneidman's Mantra, MatplotLib for Data distributions, Correlations, and Summative Statistics
Module 4	CED	Basic Exploratory Data Analytics (EDA) 5 Lessons	EDA Patterns, Interactive EDA techniques, QQ Plot for distribution diagnosis, Use Seaborn for Part and whole relationship, high dimensional data visualization techniques.
Module 5	CED	Advanced EDA 6 Lessons	Use Seaborn to visualize Time Series, trend, outliers, XMR Curve for signal detection signal detections, and use GL interactive library KeplerGL for geographic information
Module 6	CEF	Data Science Ethics 3 Lessons	Do No Harm Principles, Fairness, Five C Principles, Consent, Clarity, Consistence, Control of Transparence, and Consequences, Regulations, and case studies.
Team Project	ALL Three	Five weeks	Each team consists of 4-5 students to work through the life cycle of data visualization process shown in figure 1.

D. *Team Project Process*

Upon completing these 32 lessons, students are required to undertake a 5-week team project. Figure 1 illustrates the data visualization process guiding team projects. Section 5 will detail specific examples of these learning activities and

Identify applicable funding agency here. If none, delete this text box.

assessments, along with corresponding xAPI statements and outcomes.

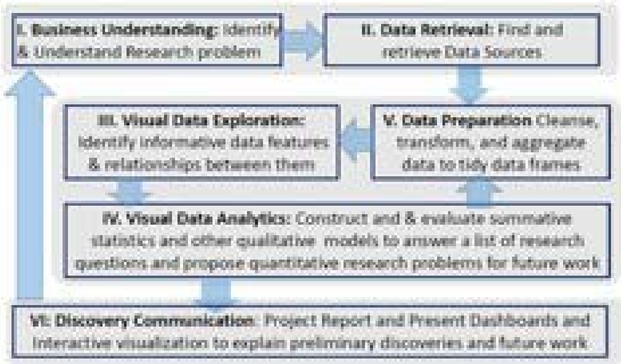

Fig.1. Team Project Process

IV. COURSE IMPLEMENTATION

In this section, we describe the implementation of ADL in the Data Visualization Course, detailing the exchange of data between Moodle and Learning Record Stores (LRS) systems, and the cloud deployment of multiple learning management systems and databases. Those familiar with ADL implementations can skip to section V.

A. Course Development Tools and System Integration

Since 2010, the first author has taught this course in both traditional and DL formats. The foundation for transforming it into an ADL course includes existing materials like PowerPoint slides, tutorials, quizzes, homework, and exams. The transition to ADL involves converting these materials into interactive content and hosting them on a website, enabling students to access the course anytime, anywhere, while also collecting xAPI data for learning activities and assessments. Key components for this upgrade are the web content authoring tool, the Learning Management System (LMS), and the Learning Record Store (LRS), for which we have chosen specific tools: Articulate 360 Storyline for content creation, Moodle as our LMS, and an LRS with a visual dashboard feature donated by Veracity Consulting Technologies (represented by the fourth and fifth coauthors). Additionally, we are exploring an AI-based tutorial system, GIFT, developed by the USA DoD. While not yet implemented for student use, GIFT is intended to enhance online tutorial interaction and reduce grading time for homework in future course iterations.

To set up the four tools discussed, they must be installed in a cloud environment with a fixed IP address, allowing for data exchange with other systems. This plug-and-play architecture and data compatibility are crucial for the TLA as outlined by [1]. Each tool comes with a user manual explaining how to integrate it with third-party TLA-compatible tools. Our integration requires just three pieces of metadata: the endpoint (IP address), key, and secret (password) from the service provider, which are copied and pasted into the service receivers. Specifically, when setting up Moodle and GIFT, the IP address, key, and secret of the LRS must be entered into their configuration pages. To help the LRS identify different data sources, it should generate unique keys and secrets for each LMS or tutoring system. For other LMS like Canvas and tools such as CaSS (Competency and Skill System [17]), we are developing adapters (termed LRSPiper) to facilitate data exchange, a task currently in progress.

B. Course Development Process

We observed three advantages for selecting Articulate 360 Storyline as our authoring tools: 1) it is easy to import Power Point (PPT) and the system converts them into interactive pages of courseware with minor activity settings, 2) the produced website can adapt to any screen size, either computer screen or smart phone screen, and 3) most importantly, it supports the publication option with xAPI data exchange format. Readers who are interested to use this tool for authoring need to get through the system user tutorials. The learning has a low floor for users of basic features but high ceiling for sophisticated users. The course development process have three major steps.

1) Course authoring and publishing: The process begins with the author opening or creating a Storyline file. The first step involves importing PPT slides into this file and then editing the content. This may include adding third-party video clips at the start of a learning activity and quizzes at the end. Once editing is complete, the author publishes the course materials. It's important to choose the xAPI data exchange format when exporting from the SCORM (Sharable Content Object Reference Model) LMS. The author must also decide on the size of the published content, which can be set at the course or learning activity level. Opting for the latter requires publishing multiple components but can reduce system load. We recommend using lesson-level size for a balance between system performance and publishing frequency.

2) Uploading the course materials into the course website with properly selected content organization structure: Our course website is http://icycle.cloud. The acronym "iCycle" stands for Intelligence Computer-supported hybrid collaborative leaning environment [5]. The structure is DS444_544/Module/lesson. Each lesson will assign a web subdomain URL starting with the endpoint of the URL concatenating with the port (8002) and file path and name. For examples, the URL for Lesson 22 of module 3 is: http://icycle.cloud:8002/DS444_544/Module3/DS444_544_M3_L22/index_lms.html .

3) Setting the content URL in Moodle: Authors need to log into the Moodle courseware website as either a site administrator or course instructor. They should select 'Edit' mode on the course's site setting page, located at the top right corner. To add content, the author first adds a lesson by clicking 'Add Topic' and then uses the '+' sign to include a learning activity or resource. A selection page will appear, where the author should choose 'xAPI Launch Link' (referred to as 'Tincan' in older Moodle versions). In the settings page of the xAPI Launch Link, the two critical fields to fill out are 'Launch URL' and 'Activity ID'. For instance, the 'Launch URL' might be the link for lesson 22 from the end of step 2, and the 'Activity ID' could be something like: http://icycle.cloud:8002/DS444_544/Module3/DS444_544_M3_L22/ . This 'Activity ID' serves as the prefix in xAPI statements for all activities in this lesson.

C. Data Collection for Learning Activities and Assessments

At present , we are one week away from the end of the course DS444_544. More than 200,000 xAPI statements with 500 megabytes of data have already been collected in the LRS https://erau.xapi.io/. The Articulate software can be configured to collect every interaction the learner had with the course website. For example, when the learner launches, quits, or resumes the course website, advances to the next page of content, selects a multiple-choice item, or tries to game the system, an xAPI statement will be saved to record the learner's activity in "who did what" format. "who" is the learner ID associated with the login ID, typically is the learner's email. The verb is the most subtle part of the learning assessment design. The default options offer about 20 verbs such as "launched, experienced, answered, completed, passed, failed, etc.". More verbs can be defined based on the needs of the assessment design. The "what" is the content ID that can be collectively mapped into the learning objectives and competencies.

After a learner completes a quiz in a learning activity, two types of summative xAPI statements are generated to indicate whether the learner passed or failed the quiz. These statements also reveal the learner's specific choices in the multiple-choice questions, identifying correct and incorrect selections. To monitor team interactions, we implemented a weekly survey for teammates. Each team member selects a weekly task, their role (lead or support) for the current week, and evaluates the previous week's task performance. Additionally, they choose a teammate for collaboration and provide peer evaluation on a five-tier scale: 1) "completed" timely, 2) "delayed and informed team", 3) "delayed and not informed the team", 4) "not-started and informed the team", and 5) "not-started and not informed team".

The weekly roles, tasks, self and peer evaluations, and artifacts are uploaded to a shared Google folder to offer the instructor a transparent view of the team dynamics. This approach has significantly improved team behaviors in both actions and communications, addressing issues observed over many years. During the final two phases of the projects, the instructor was required to conduct weekly meetings with each team to gather performance evaluations. However, for remote students or in cases of large classes where in-person meetings were not feasible, relying on data-driven formative assessments became vital for the success of collaborative learning team projects

V. LEARNING ASSESSEMNT

This section introduces a graph dashboard and insights from visual learning analytics, illustrating the clarity of online learning activities accessible via the dashboard (https://erau.xapi.io). The system enables the creation of multiple Learning Record Stores (LRSs) for various purposes, such as different courses or detail levels. The default LRS URL, https://erau.xapi.io/default-lrs/xapi/ , is necessary for configuring client applications like Moodle LMS or GIFT to manage xAPI statements. As noted in section 4, the Data Visualization course on Moodle requires this system to generate a key and password for setting up data exchange connections. A course can transmit data to multiple LRSs, and courses within the same or different LMSs can use the same LRS. However, it is advisable to use unique keys and passwords for each course linked to a specific LRS. This practice aids in easily identifying and managing different data sources and sinks, as well as monitoring the collective learning activities of a class or the performance of individual learners. A CSV file named as "statementViewerExport" can be downloaded for all xAPI records (see the Appendix for link to access the file). The file has four columns, representing the Actor (who), Verb (did), Object (what), and the activity Timestamp (when), and 206264 records, representing the number of xAPI statements collected so far in reverse chronical order.

Upon logging into the default Learning Record Store (LRS), the instructor is presented with an Analytics Dashboard in the top-level menu on the left panel. This dashboard includes several key visualizations.

Fig.2. Top: weekly activity numbers, Bottom: Top 7 user activity numbers.

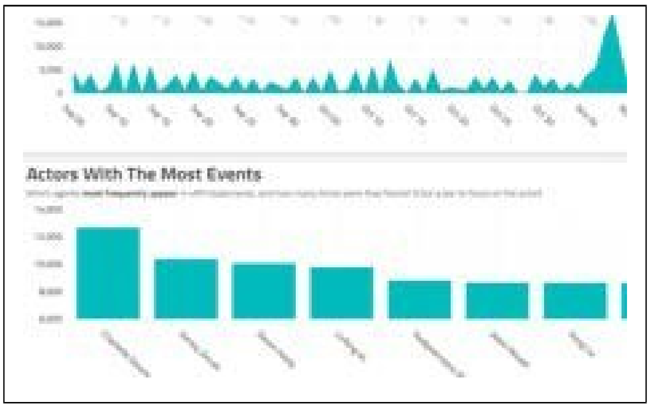

Fig.3. Top: learner activity type breakdown, Bottom: content type breakdown.

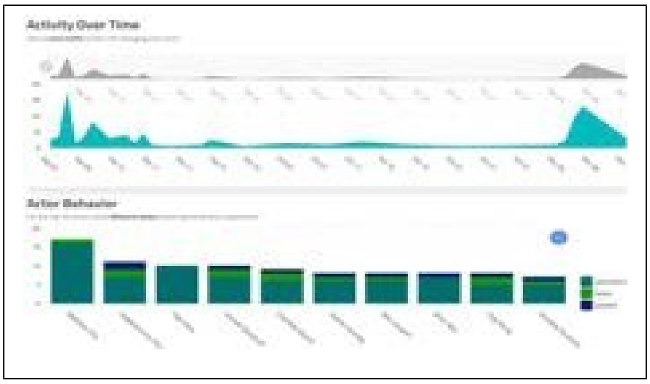

Fig.4. Breakdown of the content types for a learner's activities overtime.

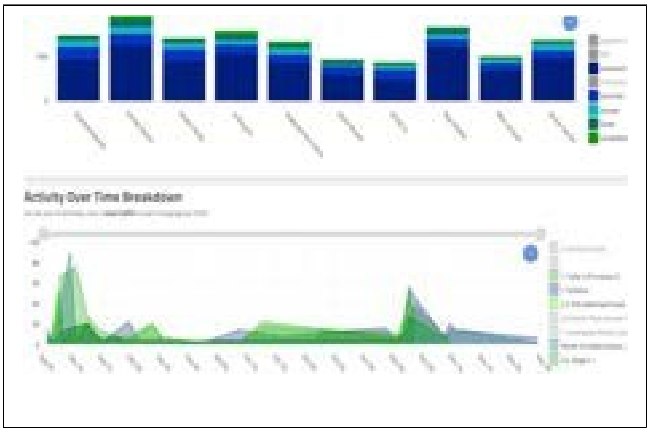

Fig.5. Top: class interaction, Bottom: learner's interaction for lesson 5.

- Figure 2: Provides an overview of class activities and individual learner progress.
- Figure 3: Breaks down the types of actions (verbs) taken by each learner. This allows the instructor to, for instance, use filters to monitor the ratio of passed to failed quizzes and identify any patterns of guessing.
- Figure 4: Enables the instructor to track a selected learner's engagement with various course contents over time.
- Figure 5: Offers a visual representation of the class's interaction with a specific lesson, such as Lesson 5.

These four dashboards collectively enable the instructor to monitor the class's overall learning activities over time, focus on the engagement with a particular lesson, or observe specific types of activities for individual students.

VI. Observations and Course feedback

A comparative analysis between the ADL course and traditional course methodologies will evaluate the effectiveness of the ADL courseware in terms of student performance and feedback. Advantages of the ADL courses are based on student feedback from the middle term survey and empirical observations compared with feedback from the same course that the first author has taught since 2010.

The course consisted of 32 students, divided into 7 teams of approximately 4-5 members each. The students enjoyed the feature of interactive learning and the accessibility and availability to learn anywhere at any time.

The following feedback from the middle term survey was summarized by Dr. Teah Cook, the associate director of the Center of Teaching and Learning Excellence. Since the class has one more week to end, the end-of-term survey results are not included.

Survey Question 1: What's working well in this class? What are the strengths of the class and which aspects are having a positive impact on your learning?

The verbatim survey responses are categorized into several themes (italicized):

Inclusive Instruction:

- The lectures have been interesting, and I learned a lot from the examples.
- Having the ability to do work/class remotely as well as in person allows for a lot of flexibility in a student schedule. I know I can travel to wherever I need to without having to worry about missing class contents because it is readily available and a zoom is provided during class for those away. This has allowed me to be able to stay on top of work even if I am not present in person.
- I think the PowerPoint lessons are helpful in getting to learn the concepts. The quizzes that come embedded with the slides are also helpful in checking the understanding and serve as the review of the lesson. The PowerPoints are helpful with homework as well as the slides snippets of code that are useful for the homework problems.
- Dr. xxx talks about things beyond the curriculum sometimes which is good because that relates to the real-life scenario.
- The strength of class is professor welcomes questions from students and answers very seriously.

Assessment:

- The homework's help to understand and test knowledge.
- The quizzes on each lesson help keep me focused and honest.

Resources:

- Having all the PowerPoint all published is great, and recording the zoom is also good.
- I enjoy the interactive PowerPoints, allows you to look back and some multiple-choice questions that make you think.

Survey Question 2: What's not working so well in this class? What specific changes could be made to improve your learning experience in this class?

- Showing coding examples from other coding languages is not useful; it is actually very confusing when trying to go back and look at examples of how to do something.
- Consider adding live caption to your lecture for those who are not native English speakers.
- Make the lessons shorter so we don't feel like everything is being thrown at us at once. Too much information to take in. Maybe do some coding during class. That would be the most helpful.
- Sometimes I feel like the class moves along really fast and it takes time to grasp certain concept. Even though they are available in an online format sometimes more explanation would be beneficial. Also sometimes content is thought that we won't reuse in the class or ever so it feels redundant.

Additional benefits were noted, particularly that online weekly surveys enhanced the transparency of teamwork for both instructors and teammates.

Some observations for this semester include a notable absence of issues such as hitch-hiking, social loafing, or students taking over others' tasks. With one week remaining until the final presentations and reports, all 7 teams demonstrated more success compared to previous semesters.

VII. Conclusion and Futre Work

This paper makes three key contributions. First, it integrates the ADL Initiative's Total Learning Architecture (TLA) into academic settings to enhance STEM education for a more diverse student body. Second, it introduces an automated assessment system for both online learning activities and team projects. This system not only upholds academic integrity but also boosts student motivation. This is particularly relevant in an era where online education, despite its benefits, faces challenges like increased cheating, exacerbated by AI tools such as ChatGPT and Google Gemini. Our approach emphasizes process over final outcomes in team project evaluations, effectively countering academic dishonesty enabled by AI-assisted plagiarism. Third, the paper outlines methods for instructors to create ADL courseware suitable for a multi-organizational hybrid learning ecosystem that enables students to learn at their own pace, anytime and anywhere.

As this is the first term since transitioning from a DL course to an ADL format, there are some limitations in our research. First, despite having over 200,000 records, the sample size is limited to 32 students, making it difficult to conduct a controlled experiment for statistically reliable conclusions. Second, although xAPI statements provide timely formative feedback to students, the courseware does not currently mandate remedial learning even when recommended. Future iterations of the course will implement compulsory remediation when necessary. For instance, progress in the course might be restricted (such as disabling forward reading options) until a student who fails a quiz successfully retakes it after reviewing the suggested materials. GIFT is being explored to post the tutorial materials so that the students can get immediate feedback and the instructor can observe students' performance timely [19]. These new course features will be deployed in the Fall 2024 semester.

The funded project associated with this paper's research spans the period from 2022 to 2025. The Fall semester 2023 is the first term the ADL course was offered. In summary, this paper can help to expand the instructional design of a Total Learning Architecture inspired ecosystem to broader audiences beyond the 11 original collaborative universities in this project.

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[19] Appendix: The xAPI Statement CVS file: https://drive.google.com/file/d/1Lu1IDfhwr-TYwQ7B-7KnqA-5GwzR-baE/view?usp=sharing.