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Visualizing TDOP+ Classroom Observation Data using Dashboards

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This is an Evidence-based Practice Paper; Research Brief. With the increase of potential data sources for learning analytics (e.g., learning management systems, technology-enhanced classrooms, and automated and manual classroom observation), learning dashboards are an emerging area of development. To be meaningful, data – especially large data sets – requires effective processing, analysis, and visualization [1]. Unlike traditional methods that depend on participants' willingness and ability to recall and report past experiences accurately (e.g., surveys, focus groups) there are now opportunities to capture real-time data on specific, observable behaviors. This can be particularly useful in engineering courses, when the instructor's goals include active learning. Learning analytics can provide a passive, non-intrusive approach to collecting data on learners' interactions with their learning contexts but introduces the complex challenge of interpreting the data [2]. Understanding the complexity of teaching practices requires more than simple statistics; it requires visualization that connects the data to the lens through which it is being analyzed. To make sense of the data, an understanding of the pedagogical and technical context from which the data was generated is required [3].

As a result, there is a missed opportunity to use information that could inform institutions about how classroom space (e.g., active learning space) is used and utilized. This type of aggregated observation data could be particularly useful to enhance instructional space design (e.g., active learning classrooms (ALCs)), as well as to support other systemic decision-making. In addition, instructors and teaching teams who want to use evidence-based approaches to improve their teaching, can struggle when trying to make sense of observational data.

As part of a multi-year research project studying instructor behaviour and tool use in a large-scale active learning classroom, we have gathered a large dataset generated from classroom observations. We saw an opportunity to address the challenge of interpreting our data by building practical, descriptive activity information dashboards that productively visualize large datasets, aiding in sense-making for users and administrators to identify patterns, and provide evidence for ALC design decisions. The focus of this paper is the design and building of the TDOP+ Tool Activity Dashboard, a set of information visualizations that:

- Processes aggregate observation data collected using the TDOP+ to visualize the data in a meaningful way to different stakeholders
- Leverages principles from ecological interface design to build a dashboard that informs design decision-making for ALCs by researchers, space designers, and administrators
- Continues the use of the project's underpinning theoretical framework, Activity Theory (AT), specifically to reveal activity system breakdowns

1. Large-Scale Active Learning Classroom Research Project

Since January 2020, we have been researching instructor behaviour in a large-scale (477 seat) active learning space at a large public institution. The data was collected in engineering and math courses. The foundation of this project's analysis is Activity Theory (AT). This holistic lens gives us language to describe and analyze observed tensions and breakdowns across teaching teams and courses before, during, and after they teach in this large ALC environment.

Key research questions include:

1. How are technological artifacts used?
2. Do these technologies align with teaching teams' pedagogical goals?
3. Does technology influence the adoption of active learning pedagogies?

Understanding how instructors understand tool affordances (i.e., possibilities for action offered to users) is crucial to design, as they influence how effectively tools are understood and used [4]. While tools can extend capabilities to achieve otherwise unattainable goals, they may also limit teaching practice [5]. The results of this work are intended to contribute to the improved usability and usefulness of this large-scale active learning space and inform the design of similar spaces that might be developed in the future.

1.1. Developing the TDOP+ (Teaching Dimensions Observation Protocol for Active Learning Classrooms)

Earlier in the project, we detailed the process of combining two existing protocols (Teaching Dimensions Observation Protocol (TDOP) and the Active Learning Classroom Observation Tool (ALCOT)) into a new protocol, the TDOP+ [6]. The TDOP+ is pedagogically agnostic and aligns with Activity Theory, enabling structured, scalable documentation of intrinsic and extrinsic classroom orchestration, which underpins the dashboard visualizations presented.

When using the TDOP+, researchers can code for 76 observed behaviors. The TDOP+ was modified to include all observed instructional technologies used by instructors in the ALC. The data is further categorized using metadata into Teaching Dimensions[7], Pedagogy-Space-Technology (PST) Framework [8], and Classroom Orchestration [9]. Data points are derived from observed state events (e.g., they have a time duration like lecturing) or point events (e.g., they occur or do not occur like frequency of tool use). This added layer of analysis enables us to use the data's metadata to visualize activity in a way that answers the research questions. To give a sense of the volume of data, each observation generates hundreds of rows of transactional data, with observations averaging 164 rows per 50-minute class session.

2. TDOP+ Dashboard Design

2.1 Used theoretical framework (AT) to align data to analytic requirements

We built the TDOP+ Dashboard to visualize system breakdowns, focusing on contradictions between what a user wants to do and what their tools enable them to do. The Tool Activity Dashboards highlight how instructors (subjects) use—or do not use—tools to achieve teaching goals (object of activity; see Figure 1). We analyze the use of both built-in (e.g., displays, microphones) and brought-in (e.g., laptops, handouts) tools in enabling or constraining teaching activity. Our analysis also considers divisions of labour, including instructors' physical movement and expanded roles (e.g., providing technical support during class).

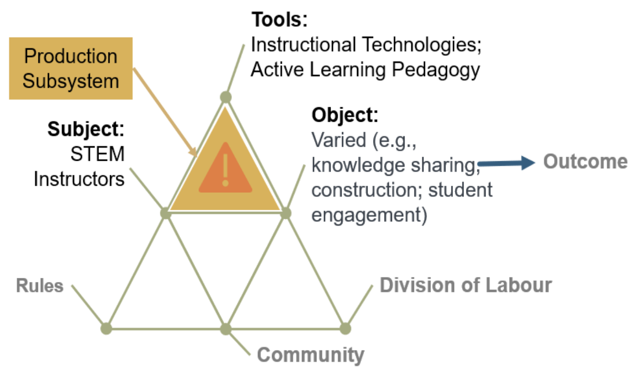


Figure 1: Generalized breakdowns in an ALCs Production Subsystem

Despite the connotation of the term, breakdowns are key for transformation [10] because digging into these tensions generates recommendations on how to resolve contradictions based on their nature (i.e., downwards contextualization (tool use), and upwards contextualization (i.e., administrative challenges)). Observing how users interact with the system and how they cope with breakdowns in ALC activity systems reveals new practices that can be used to inform design specifications [11].

2.2 Used Work Domain Analysis to guide ecological interface design

The overall TDOP+ Tool Activity Dashboard design is based on an abstraction hierarchy grounded in Activity Theory, which relates the artifacts and actors in the classroom within the context of the university system in which this activity is occurring. Drawing on ecological interface design (EID) heuristics [12], including work domain analysis [13], is a helpful interface design methodology for this project because it focuses on the analysis of the domain as a system instead of on a specific user (e.g., one instructor or one course).

An abstraction hierarchy uses five-levels of functional decomposition to move up and down the system, with lower levels describing the physical components and the higher levels defining its goals and purposes [14]. Drawing from a previous work domain analysis of the ALC, we built a three-level (tool-level, course-level, project-level) screen hierarchy that visualizes the complexity of socio-technical tool mediation within an active learning classroom. In Table 1, see a simplified representation of the abstraction hierarchy represented in the TDOP+ Tool Activity Dashboard.

Table 1: Simplified Abstraction Hierarchy for the TDOP+ Tool Activity Dashboard

Level of Abstraction	Focus of Level	TDOP+ Tool Activity Dashboard
Functional Purpose	System Goals and Purposes	N/A
Abstract Function	Underlying laws and principles	Pedagogy (e.g., active learning); student engagement
Generalized Function	Processes to achieve laws and principles	Tool use with co-occurring activities (e.g., timer use during break out activity)
Physical Functions	Physical components and equipment	Instructional Technology (e.g., display, microphones, timer)
Physical Form	Condition and location of equipment	N/A

3. TDOP+ Dashboard Prototypes

This paper focuses on the rationale for information design and data visualization rather than navigation or usability features. Future research might include user experience testing to evaluate the clarity and accessibility of these dashboards for their intended audiences. However, we have considered user experience in the prototype design. For example, each TDOP+ Dashboard includes consistent usability, including multiple user-controlled data splicers. Researchers can manipulate filters to narrow or expand data by focal actor (e.g., instructor, students), course details (e.g., year, term), or specific tools. The dashboard dynamically updates to display only the data that aligns with the user's selections. To build the dashboards, we use Python and Power BI.

3.1 Dashboard Prototype: Physical Functions (Tool Activity > Tool-level)

The Tool-level Activity Dashboard is the lowest level of abstraction and represents the physical function layer of abstraction, see Appendix A: TDOP+ Tool Activity > Tool-level Dashboard (Prototype v1). At this level of abstraction, we are using the Dashboard to visualize tool use (e.g., frequency). While AT uses the term tool broadly (i.e., to describe any mediator of human activity [4], including language and abstract concepts (e.g., pedagogy)), we are using "tool" to describe instructional technology artifacts. An artifact could be any technology such as a part of the Audio Visual (AV) system in the classroom, an analog technology (e.g., whiteboard), or a device brought in by the instructor such as a laptop.

At this level of abstraction, tool data visualized includes tables and figures showing how many courses it was used in, who used it, and any technical issues coded during tool use. To add context to tool use, tools have modifiers which further describe the tool. For example, during an observation, the researcher would code Display (DI) as well as how many inputs were used to populate the display regions. This screen also includes a table with further details, including what (if any) activity state co-occurred with the tool use and any technical issues or notes relevant to that use.

For breakdowns, we are looking for changes in behaviour (e.g., tool abandonment) and difficulties using tools (e.g., technical issues). An example of downwards contextualization revealed by this Dashboard would be that tool use decreases over time.

3.2 Dashboard Prototype 02: Generalized Functions (Tool Activity > Course-level)

The Course-level Dashboard represents the generalized functions level of abstraction. Moving up in the levels of abstraction, this Dashboard, see Appendix B: TDOP+ Tool Activity > Course-level Dashboard (Prototype v1), connects how tools are used to support different instructor-centred activities during different class activity segments (e.g., lecturing, individualized instruction). While tool use statistics are interesting to explore tool uptake and patterns of use, focusing solely on tools without considering the broader environment (i.e., what else is happening in the ALC) and community (i.e., who else is in the ALC), risks an incomplete approach to analysis [15]. This level of abstraction introduces the relationship between observed behaviour and the analytical taxonomies (PST framework and classroom orchestration).

At this level of abstraction, we introduce the class timeline visual, *Tool use by focal actor*. This is a custom visual that uses time (i.e., the duration of a class session) to contextualize tool use by indicating on a timeline when a tool is used and by which focal actor (e.g., instructor, teaching assistant, student). Other visuals capture tool use by instructor, tool use by co-occurring state behaviour, number of technical issues, if tool use was observed during an extrinsic or intrinsic classroom orchestration activity, and percentage of overall tool use by focal actor. Located in the bottom row of the dashboard, these visuals provide supporting information for the primary graphics. We focus on instructor behaviour, but include generalized data on student activity, especially for student-centered, active learning activities (e.g., responding to an instructor question).

For breakdowns, we are looking for unexpected instances or patterns of activity. For example, if regrouping is coded after using a tool this indicates something derailing the class plan. If this was a pattern, it would lead to further analysis.

3.3 Dashboard Prototype 03: Abstract Functions (Tool Activity > Project-level)

The Project-level Activity Dashboard visualizes the data in aggregate, focusing on two summary visuals: a comparison of the tools as they are used across courses and a course overview table that displays at-a-glance any data outliers. At the abstract function level, which capture the underlying laws and principles of the system, the project's frameworks are most explicit [12].

In the *Course Overview*, see Appendix C: TDOP+ Tool Activity > Project-level Dashboard (Prototype v1), observed behaviours are summarized in bars using metadata associated with behaviours in the observation ethogram. These taxonomies include teaching dimension (e.g., instructional technology, pedagogical strategies, cognitive engagement, etc.), classroom orchestration (e.g., intrinsic teaching, extrinsic teaching) and the active learning ecosystem (e.g., technology, space, pedagogy). The Course Overview table also details the number of instructors present, the number of technical issues (or notes) recorded, the total number of tools used, and a tool count of how many times those tools were used.

For breakdowns, through the summary table, we are looking for courses with activity bar graphs with abnormal percentages of classroom activity (e.g., most of the class being coded as extrinsic teaching) that require further analysis by moving down into the generalized functions level of abstraction.

4. Challenges using dashboards

As we developed the data set and the visualizations, challenges were encountered:

- **Using classroom observation data objectively.** While observation protocols have been found to be more objective than faculty self-reports and student evaluations [17], their use presents challenges such as ensuring the reliability of observational data (including inter-rater reliability and real-time coding pressures), managing time commitments, minimizing disruptions to class dynamics, and addressing observer bias and interpretation [18]. After addressing these concerns, researchers must select or develop an observation protocol that aligns with their specific research goals. The proliferation of protocols over the past decade has made this selection process increasingly difficult for both practitioners and researchers [19].

- **Operationalizing AT is an ongoing challenge.** AT is a continuously evolving framework, and researchers navigate its evolving framework without a shared set of practices [4], [20], [21]. While still in progress, the TDOP+ Tool Activity Dashboard continues the work of other established researchers who use AT and who have shared their methods for operationalization for different stages of research projects (e.g., interview protocols) [20]-[24].
- **Building Dashboards requires cross-disciplinary expertise.** Design (especially when embedding a complex theoretical framework) requires careful attention to usability and the varied needs of instructors, researchers, and administrators. While fields like ecological interface design offer system design heuristics, there is limited research on visualizing teaching activity in ways that support feedback and reflection across stakeholder groups. As interest in learning analytics grows and tools like Power BI and Tableau become more accessible, the design of learning dashboards will continue to evolve.

5. Future Work

For now, the TDOP+ Tool Activity Dashboards focus on one aspect of the activity system – tool mediation in an active learning classroom. Future work could involve developing dashboards for specific audiences, with additional dashboards developed to reveal more active learning classroom dynamics. Talbert et. al [16] identified several areas worthy of future active learning classroom research, including longitudinal studies as well as research that focuses on technology and pedagogy. This dashboard offers a rare insight into tool use at an aggregate level over multiple terms. Our project goal is to provide engineering education researchers, educational technologists, and classroom designers with a tool for examining classroom practices. We see great value in enabling instructors to reflect on their teaching practice and assist them in making evidence-based changes to their course design via instructor-facing dashboards.

6. Conclusion

Researchers long ago identified that AT's dynamic complexity also hinders its broader usability [25]. The abstract and nuanced language of AT can be difficult to interpret, complicating the translation of theoretical concepts into practical design interventions and strategies [26]. When using AT, researchers are required to make the abstract concrete through (existing, modified, and net-new) operationalization efforts. For this project, the dashboards are the culmination of this operationalization effort. We plan to release the dataset collected using the TDOP+, further encouraging others to complete their own observations, add to the dataset, and explore building their own flexible information dashboards.

ALCs are of particular interest to Engineering Education practitioners who seek to develop graduate attributes (e.g., problem-solving, communication, and teamwork skills) in large classes, using technology-mediated active learning strategies to meet their goals (e.g., to better prepare students for the demands of 21st century STEM careers) [27]. With greater understanding of how instructors are using and utilizing active learning classrooms, space designers and administrators can continue to support the transition from more traditional lecture-based instruction to more engaging and interactive learning environments.

References

[1] K. Börner and D. E. Polley, *Visual Insights: A Practical Guide to Making Sense of Data.* 2014.

[2] S. Dawson *et al*, "“Seeing” networks: Visualizing and evaluating student learning networks," Australian Learning and Teaching Council, Canberra, 2011. Available: http://research.uow.edu.au/content/groups/public/@web/@learnnet/documents/doc/uow115678.pdf

[3] L. Lockyer, E. Heathcote and S. Dawson, "Informing Pedagogical Action: Aligning Learning Analytics With Learning Design," *Am. Behav. Sci.,* vol. 57, *(10),* pp. 1439–1459, 2013. DOI: 10.1177/0002764213479367

[4] D. H. Jonassen, "Revisiting activity theory as framework for designing student-centered learning environments," in *Theoretical Foundations of Learning Environments*, 1st ed., D. H. Jonassen and S. M. Land, Eds. Lawrence Erlbaum Associates, Inc., 2000, pp. 89–122.

[5] V. Kaptelinin and B. Nardi, "Affordances in HCI: Toward a mediated action perspective," in Chi 2012, Austin, TX, 2012.

[6] A. Van Beek and S. McCahan, "Adaptation of a classroom observation protocol for active learning," in *Canadian Engineering Education Association,* June 2021.

[7] M. T. Hora, "How the TDOP Illuminates the Multidimensional Nature of Active Learning in Postsecondary Classrooms," *Science Education,* vol. 99, *(5),* pp. 783–818, 2015.

[8] D. Radcliffe *et al*, "Designing next generation places of learning: Collaboration at the pedagogy-space-technology nexus: ALTC priority project #627" Australian Learning & Teaching Council, Australia, 2008.

[9] P. Dillenbourg, "Design for classroom orchestration," *Computers and Education,* vol. 69, pp. 485–492, 2013. Available: http://dx.doi.org/10.1016/j.compedu.2013.04.013. DOI: 10.1016/j.compedu.2013.04.013.

[10] S. Bodker, *Through the Interface: A Human Activity Approach to User Interface Design.* Taylor & Francis, 1989.

[11] U. Hedestig and V. Kaptelinin, "Re-contextualization of teaching in a videoconference-based environment," in *CSCL 2002,* 2002, pp. 179–188.

[12] C. M. Burns and J. R. Hajdukiewicz, *Ecological Interface Design.* 2004. DOI: 10.1201/9781315272665.

[13] N. Naikar, *Work Domain Analysis: Concepts, Guidelines, and Cases.* 2013.

[14] A. M. Bisantz and K. J. Vicente, "Making the abstraction hierarchy concrete," *Int J Hum-Comput St,* vol. 40, *(1),* pp. 83–117, 1994. DOI: 10.1006/ijhc.1994.1005.

[15] G. Gay and H. Hembrooke, *Activity-Centered Design: An Ecological Approach to Designing Smart Tools and Usable Systems.* Cambridge, MA: MIT Press, 2004.

[16] R. Talbert and A. Mor-Avi, "A space for learning: An analysis of research on active learning spaces," *Heliyon,* vol. 5, *(12),* pp. e02967, 2019. DOI: 10.1016/j.heliyon.2019.e02967.

[17] H. W. Marsh, "Students' evaluations of university teaching: Dimensionality, reliability, validity, potential biases and usefulness," in *The Scholarship of Teaching and Learning in*

Higher Education: An Evidence-Based Perspective, R. P. &. Perry and J. C. Smart, Eds. 2007. DOI: 10.1007/1-4020-5742-3_9.

[18] M. Hora and J. Ferrare, "A Review of Classroom Observation Techniques in Postsecondary Settings," *WCER Working Paper no. 2013-1,* 2013.

[19] J. Esson *et al*, "Recent Developments in Classroom Observation Protocols for Undergraduate STEM: An Overview and Practical Guide," *Journal of College Science Teaching,* vol. 52, *(1),* pp. 3–5, 2022. DOI: 10.1080/0047231X.2022.12315663.

[20] Y. Engeström, "From Learning Environments and Implementation to Activity Systems and Expansive Learning," *Actio: An International Journal of Human Activity Theory,* vol. 2, pp. 17–33, 2009.

[21] D. Mwanza, "Where theory meets practice: A case for an activity theory-based methodology to guide computer system design," in *Interact 2001,* 2001.

[22] M. Duignan, J. Noble and R. Biddle, "Activity theory for design from checklist to interview," in *Human Work Interaction Design: Designing for Human,* 2006, pp. 1–25.

[23] V. Kaptelinin, B. Nardi and C. Macauley, "Methods and Tools: The Activity Checklist," *Interactions,* vol. 6, *(4),* pp. 27–39, 1999. Available: http://interactions.acm.org/archive/view/july-aug.-1999/methods-tools-the-activity-checklist1.

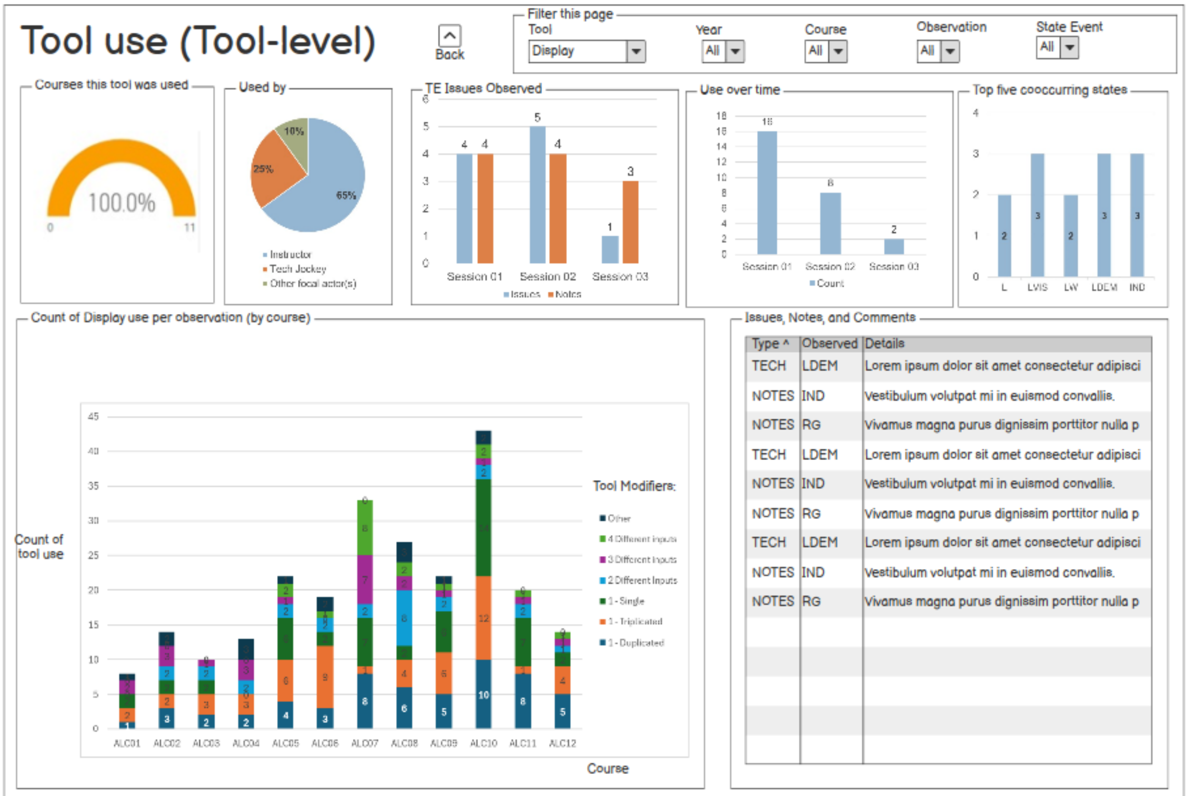
[24] D. H. Jonassen and L. Rohrer-Murphy, "Activity Theory as a Framework for Designing Constructivist Learning Environments," *ETR&D,* vol. 47, *(1),* pp. 61–79, 1999. Available: https://www.jstor.org/stable/30220230. DOI: 10.1007/BF02299477.

[25] B. Nardi, *Context and Consciousness: Activity Theory and Human-Computer Interaction.* Cambridge, Mass.: MIT Press, 1996.

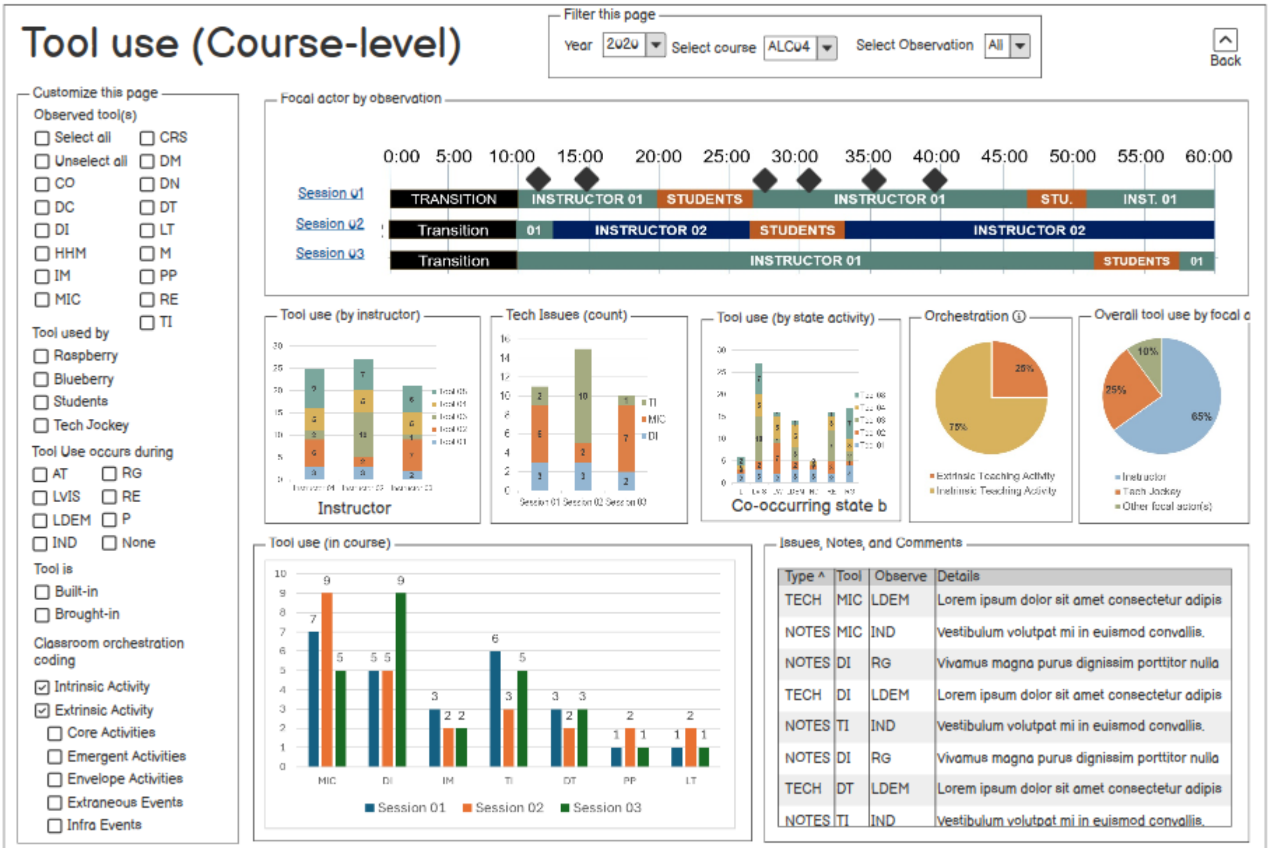
[26] L. Yamagata-Lynch, *Activity Systems Analysis Methods : Understanding Complex Learning Environments.* New York: Springer, 2010.

[27] R. J. Beichner *et al*, "Introduction to SCALE-UP: Student-centered activities for large enrollment university physics," 2000.

Appendix A: TDOP+ Tool Activity > Tool-level Dashboard (Prototype v1)



Appendix B: TDOP+ Tool Activity > Course-level Dashboard (Prototype v1)



Appendix C: : TDOP+ Tool Activity > Project-level Dashboard (Prototype v1)