UW System FY16 Innovation Program Project Final Report

Learning Analytics Tool Chest –
Optimization of Analytics & Recommendation Tool

UW-Madison

[redacted]

Unfortunately, at this time we do not have capacity to produce a video.

FINAL PRESENTATION – QUESTIONS:

Would you and/or your team be interested in organizing a 5-minute presentation describing your project at the Spring 2016 ITMC Conference scheduled for April 18-19 in Wisconsin Dells?

- [x] Yes, I/our team will give an in-person, 5-minute presentation at the Spring ITMC Conference in April.
- [ ] Yes, I/our team will give a virtual, 5-minute presentation at the Spring ITMC Conference in April.
- [x] Yes, I/we approve of having our ITMC presentation recorded for posting on the website.
- [ ] No, I/our team declines the opportunity to give a 5-minute presentation at the Spring ITMC Conference.

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UW-Madison

I. Executive Summary

Learning analytics is an emerging field, and as such, underlying infrastructure and tools are still immature relative to the large, enterprise learning technology systems we are used to. UWS has contributed substantial resources to developing the innovative practice of learning analytics, starting with a Growth Agenda Grant awarded in 2012. Over the past four years, significant organizational capacity has been built to support analytics for student success, and the University of Wisconsin System has been consistently recognized as a leader in the application of systemic learning analytics.

A major outcome of the Growth Agenda Grant was the development of a Learning Analytics Tool Chest (LATC). The LATC came into existence because of its innovative promise in the realm of student success. Great effort was exerted to ensure as much sustainability as possible. However, optimization and maintenance of the LATC is seen still as "innovation" and not "operational" so a funding chasm has emerged. By investing a small amount of financial support from the FY16 Innovation Project Program (IPP), the incremental gains from this proposal moved the UWS LATC towards a more reliable and robust position. Having the underlying infrastructure and tools in place means that momentum can continue in cultural acceptance and adoption of learning analytics practices.

The remainder of this report focuses on how the *Learning Analytics Tool Chest – Optimization of Analytics & Recommendation Tool* funded IPP was carried out at UW-Madison. The underlying problems the LATC addresses and project objectives will be discussed in section II. Section III will focus on how the LATC was bolstered. Results, discoveries, and accomplishments will be detailed in Section IV, along with a discussion of risks encountered and risk mitigation plans. The final section, Section V, will focus on conclusions, lessons learned and recommendations.

II. Purpose and Objectives

Learning analytics technology provides new opportunities for learners and educators to make the most informed, outcomes-driven decisions to positively impact student's academic achievement. Learning analytics (LA) is a big idea that can lead to educational transformation. LA considers the learner's needs beyond simple grade point metrics and provides instructors with new perspectives into the learning process, as well as key insight into the behavioral patterns and academic proficiencies that drive learner success. Additionally, instructors can use LA to assess their pedagogy and adapt it according to empirical measures. Learning analytics can harness the power of predictive analytics to identify at-risk learners early and proactively intervene, possibly changing the trajectory of a student. Likewise predictive analytics can find under-engaged students and provide new outreach strategies.

Learning analytics can empower students as they progress through their academic career. They can monitor their progress and risk, get just-in-time cognitive scaffolds delivered at the moment of learning, find ways to alter their behavior and find the most effective help resources, develop personal learning networks, and explore effective paths to graduation and promising careers.

Learning analytics can help faculty leverage the powerful data at their disposal to truly support a continuum of learners – from those at risk to those successful students that can be guided to greater heights. LA can be successfully applied in large enrollment course where teachers wish to provide a more personal level of support but simply cannot because of the sheer size of the course.

Learning analytics can provide efficiencies for administrators. Advisors and other student success professionals can be afforded the opportunity to provide early and frequent, real-time interventions across a student's course-load. Administrators can use LA to monitor course progression to see which paths are most successful for certain types of students. LA can provide administrators with an overview of academic health at any given time within a single course, or across a program. High-level LA views provide insight into new institutional strategies that can help keep learners on-track and on-time for graduation.

Despite all the promise of learning analytics, it is still an emerging field. Existing, UWS, Common Good infrastructure and tools are still immature in terms of analytics power. While, as a complex system, we have reached impressive heights in shared architecture as demonstrated by system-wide enterprise architecture for many learning technologies, the underlying analytics architecture requires a significant overhaul as we prepare to serve next generation learning environments, drastically changing pedagogical strategies, external demands for accountability, and student expectations. UWS has contributed substantial resources to developing the innovative practice of learning analytics, starting with a Growth Agenda Grant awarded in 2012. Over the past four years, significant organizational capacity has been built to support analytics for student success, and the University of Wisconsin System has been consistently recognized as a leader in the application of systemic learning analytics.

A major outcome of the Growth Agenda Grant was the development of a Learning Analytics Tool Chest (LATC). The LATC came into existence because of its innovative promise in the realm of student success. The 3-year pilot project was important as it sought to introduce new theory, tools, and practices simultaneously to multiple campuses across UWS. The pilot started with a single tool, Desire2Learn's Student Success System, and then expanded into a more robust offering of tools to meet the needs of a diverse teaching population. These learning analytics tools provide new opportunities for learners and educators to make the most informed, outcome-driven decisions to positively impact student's academic achievement.

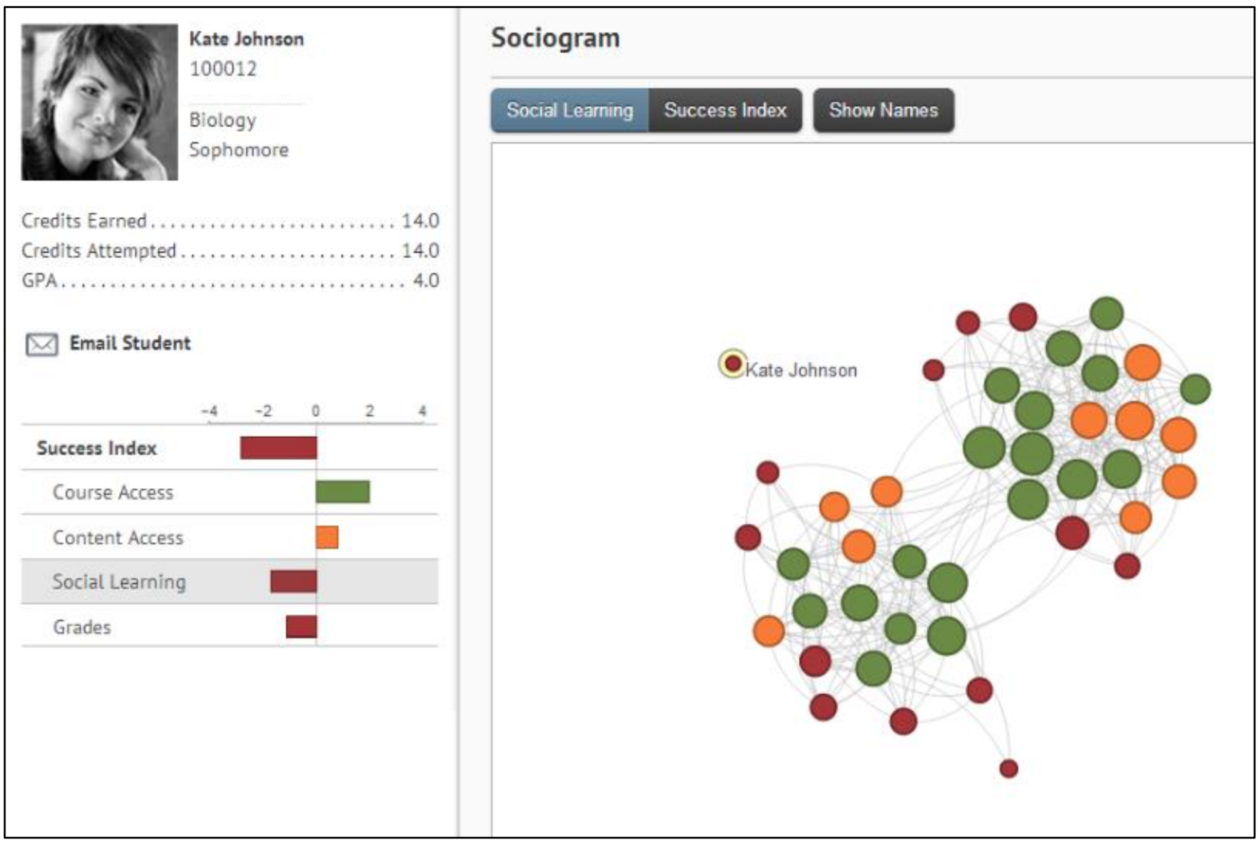
Currently, the UWS Learning Analytics Tool Chest consists of four tools. Each tool is briefly described here, and then in more detail in Appendix A.

A. Desire2Learn's Student Success System (S3)

The initial tool piloted by the Growth Agenda Grant was Desire2Learn's Student Success System (S3). S3 is a probabilistic modeling tool that relies heavily on historic data to provide course-level predictive analytics with sophisticated dashboarding and visualization options. See Figure 1 for a screen shot.

Figure 1

Screen Shot of D2L's Student Success System



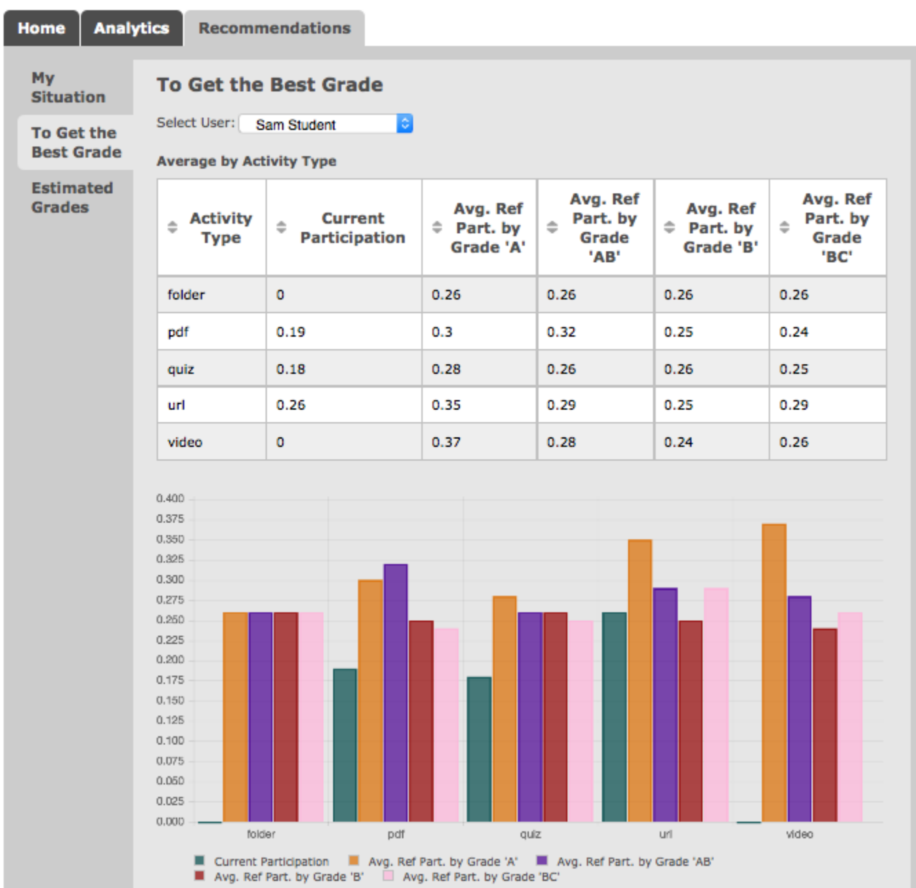
When it became apparent that a "one size fits all" approach to learning analytics would not be appropriate, an evaluation was undertaken to find other possible extensible tools in the student success analytics realm.

B. Analytics & Recommendation Plug-In (A&R)

The Analytics & Recommendation Plug-In (A&R) was selected as another tool to integrate into the LATC because, similar to S3, it was based on predictive analytics techniques, but the data was exposed in drastically different ways. A&R displays data by tool/activity type allowing data to be interrogated at a more micro level. Instructors are able to see single, comparative, and global analytics for all students within their course.

A unique feature of A&R is the student-facing dashboard. A central tenant of learning analytics theory is that data should be used to empower students—by offering a student dashboard, A&R embodied this. Natively, the recommendation component displays a comparison of a student's current participation alongside the behavioral profile of the student scoring the highest grade in an historic offering of the course. This allows a student to plainly see: i) which activities they should be exerting more effort on and ii) how much additional time they should dedicate to the activity types. As a direct result of the IPP, the recommendation component of A&R was substantially upgraded to a more statistically reliable clustering technique. Figure 2 shows a screen shot of A&R.

Figure 2
Screen Shot of Analytics & Recommendation Tool

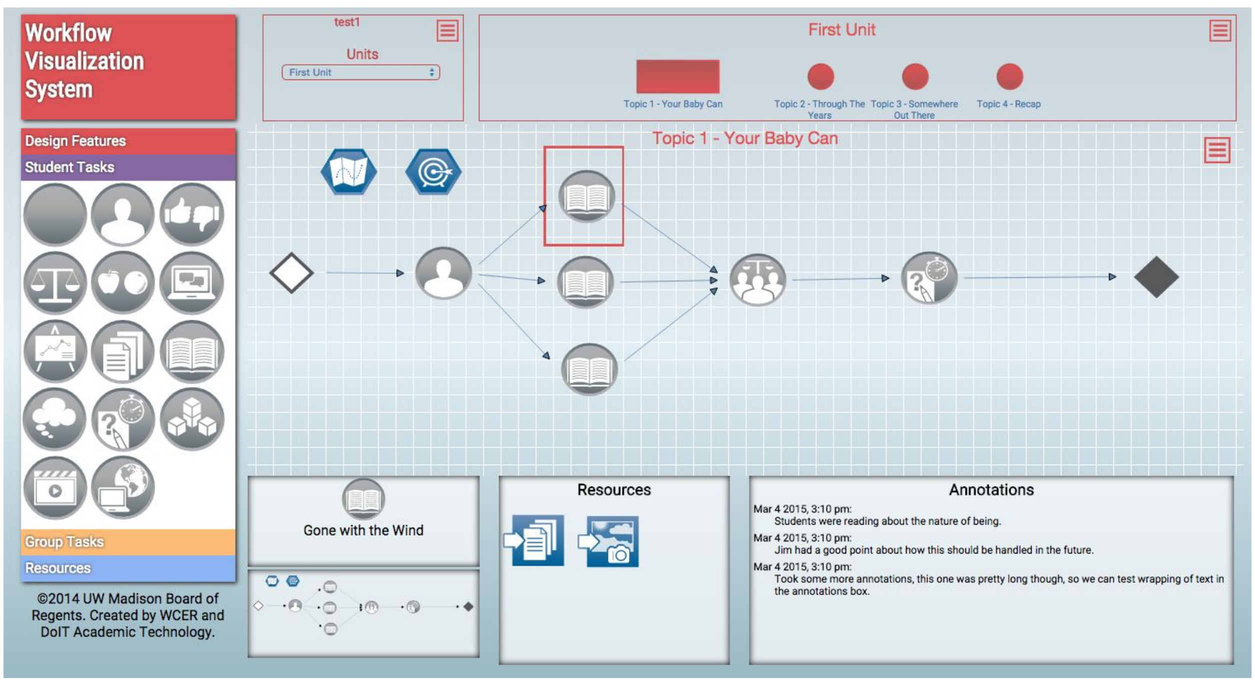


Activity Type	Current Participation	Avg. Ref Part. by Grade 'A'	Avg. Ref Part. by Grade 'AB'	Avg. Ref Part. by Grade 'B'	Avg. Ref Part. by Grade 'BC'
folder	0	0.26	0.26	0.26	0.26
pdf	0.19	0.3	0.32	0.25	0.24
quiz	0.18	0.28	0.26	0.26	0.25
url	0.26	0.35	0.29	0.25	0.29
video	0	0.37	0.28	0.24	0.26

C. Workflow Visualization Tool (WVT)

Designed by a graduate student and instructor Alan Hackbarth, the third tool integrated into the LATC was the Workflow Visualization Tool (WVT). WVT is different from S3 and A&R in that it moves away from a reliance on historic data and predictive analytics, and focus is more firmly placed on the side of curriculum and modules. WVT provides visual representation of course design, lesson plans, and individual activities, representing how an instructor intends students to interact with the course - and then provides analytics on those activities and how students actually interact with the course. It also provides provisions for the instructors to be able to annotate each activity, to keep their own records on how instruction may have differed from the original plan. Figure 3 shows a screen shot of WVT.

Figure 3
Screen Shot of Workflow Visualization Tool



D. Pattern

The final tool currently in the LATC is licensed from Purdue University. The tool is called Pattern and is a Quantified Self Student (QSS) tool. This tool is a rudimentary version of a “fitbit for learning” in which a student records (self-reports) information about her study and learning behavior/activities, and subsequently rates her productivity. The tool then aggregates the data and provides robust visualization about learning productivity. This tool not only allows a student to be more self-reflective as a learner, but also provides extrinsic motivation for some students. Pattern opens a new world of data curation possibilities for the field of learning analytics broadly, but more specifically, for students that attend a UWS school.

Figure 4 shows a screen shot of the student Dashboard feature of Pattern.

Figure 4
Screen Shot of Pattern

The *Learning Analytics Tool Chest – Optimization of Analytics & Recommendation Tool Innovation Program Project* focused on optimizing the LATC generally, and specifically on one of the tools that is garnering a lot of interest from faculty and instructors - the Analytics & Recommendation (A&R) tool. While the A&R tool was fully integrated and ready for pilot in Fall 2015, a major objective of the project was to do some back-end coding work that would greatly optimize the A&R tool. As the tool was originally created, each individual student is compared against *the single highest scoring* student from a historical course. In statistical terms, this makes the tool highly susceptible to outliers—either in grade or in level of activity.

This treatment is rectified by some changes to the software using clustering techniques. The other major objective of this project was to provide general maintenance to known and reported bugs, glitches, and if budget allowed, feature requests. While minimal cost was required, these efforts greatly impact the validity of the data exposed by the tools as well as the users' experience.

III. Organization and Approach

General optimization of the LATC was handled with standard project management techniques. As the LATC was rolled out for pilot (for the first time in Fall 2015) bugs, glitches, and code fixes were handled as reported. Usability enhancements were considered in order of priority and were addressed if financially viable. These components were all handled as part of a normal service operation.

After examining the algorithm for A&R, the optimization was approached as a fixed clustering technique, as it was not viable to create a more flexible model, configurable by each campus. Having a configurable campus model whereby the same model would be applied to all students at an institution, with adjusted weights on particular (statistically-derived) activities could potentially be more effective; however resources did not permit us to take that route. Instead a clustering technique was incorporated that compared a single student to categorical profiles created from historic offerings of a course. For example, Student A's behavior to date suggests that she will receive a B+. This approach removes some noise from the predictions and allows a normalized behavioral profile to be created. At the time of this report, the algorithm optimization has not been deployed for live use, so the efficacy of the clustering technique still needs robust validation after a semester of piloting.

Tasks completed to fulfill this objective follow.

- **Algorithm Optimization—**export historic behavior data for analysis
- **Algorithm Optimization—**Clean, transform, and analyze behavior data to determine which path to take to implement back-end algorithm optimization for A&R
- **Software Development—**implement the selected algorithm optimization solution

With the first major objective achieved, the team turned their focus to more general optimization of the LATC. To prioritize fixes and feature requests, a LATC Technical Reliability Study was undertaken in which the campus liaisons worked with instructors on their campus to gather evidence of performance issues, bugs, glitches, and requests for improvements for the LATC tools. Using the evidence collected during the LATC technical reliability study, the requests were examined and prioritized.

Tasks completed to fulfill this objective follow.

- **Algorithm Optimization—**Original code included all roles in the algorithm calculations; all roles were removed EXCEPT for students so that estimates were purely based on student behavior (rather than having instructor/TA/administrator behavior contaminate the calculations).

- **User Interface Improvements—**Many changes were made to displayed metrics to ensure reports were more meaningful and actionable to users (students and instructors). Students are also now able to compare their behavior to the grade clusters (A, AB, B, BC, C) rather than to a single high-performing student; this allows a range of behavior to be captured.
- **Display Improvements—**Reported visual display issues were addressed. Colors of the data visualizations were changed to allow for more distinguishable distinction. Display issues within Firefox were also addressed.
- **Performance Improvements—**Code was added to allow for more efficient response times, as well as loading performance. This was particularly critical as many of the instructors who have emerged as most interested in the tools are those with very large courses and/or very extensive use of fully online activities.
- **Software Development and Testing—**The clustering technique selected for the algorithm is implemented into the tool and has been tested in development.
- **Change Implementation—**Changes were finalized based on software testing feedback.
- **Deployment—**Algorithm optimization is live for future semesters.

IV. Analysis and Findings

Many of the results from this IPP *support* innovation even if they themselves are not innovative. As previously discussed, maintenance and upkeep of innovation such as the LATC are often neglected after the initial excitement about an innovation wears off. This project was purposefully task-oriented to provide a better user experience for UWS instructors and students using a learning analytics tool to spur innovation in teaching and learning. The results of this project will lead to a better user experience of the LATC.

All identified bugs, glitches, and code fixes were prioritized, documented, and in most cases handled in a timely manner, something that otherwise would have not happened since the LATC is not a centrally supported tool. The LATC is markedly more reliable now, at the end of the 120-day period, than it previously was. Furthermore, the LATC is reliable and technically stable enough for expansion in the future. The A&R tool specifically is now more realistically actionable for students looking to be more self-reflective learners, as well as for teachers looking to be directive in their student support mission.

A task-oriented approach to this IPP means that risk was fairly minimal. However, there were some concerns with getting non-IPP resources for algorithm optimization. This did prove to be the case and was mitigated by using the limited statistical expertise available to the team for one generic clustered algorithm rather than campus-specific models. A second risk was not having Teaching & Research Application Development (TRAD) capacity to complete the development work. Since TRAD works on a Time & Material basis, capacity could not be guaranteed, until a funding stream was established. However, this risk never came to bear as timely notification from the IPP Program Officers was delivered and we were able to secure TRAD capacity.

Three smaller risks surfaced during the algorithm optimization phase of the project. While some risk was interjected, we prioritized the issues and addressed them, leaving some feature requests unfulfilled. Therefore, all three of these risks were mitigated. The three issues were: i) an unexpected memory issue was discovered related to the initial retrieval of data for A&R, ii) all development work has been done in non-production courses; once all optimizations have been implemented, testing with real-world courses and additional load testing will need to be scheduled, and iii) A&R was designed with the assumption that an individual instructor will access the tool only for a single course, as opposed to use by someone teaching multiple courses. This last issue may pose a risk as some data elements retrieved will be stored locally to streamline the use of the tool. Research was undertaken to produce solutions for the issues and all were addressed in the second phase (60-120 day) of the project within the current scope and budget. The three issues are common in customizing software and known solutions exist.

V. Conclusions and Recommendations

While this task-oriented project is now officially closed, the outcomes of this work, combined with UW-System's previous support of innovation in student success leveraging learning analytics shows a continued demand for a centrally supported solution in this realm. We hope the existing LATC is seen as an evolutionary process. As described above, a thorough evaluation of the A&R algorithm optimization will be necessary in the future to ensure that the clustering technique is effective and valid.

Additionally, since LA is a promising innovation in education, many new open-source or potentially extensible tools have "come to market" in the past 16 months (the last time a viability study was undertaken), and continued systematic exploration of this area should happen on a more frequent basis, taking into account needs of faculty and students.

Finally, most of the current tools are LMS-based, meaning that the majority of the data driving our actionable intelligence is based on data from a single source. While some tools ingest Student Information System (SIS) data, those elements are minimal (and should continue to be so until UWS has privacy policies in place specifically around LA practices). However, across our great University of Wisconsin System, there is a large range of educational technology tools available to us. Using the modularized system designed for interoperability (see Appendix B), UWS should undertake an inventory of data-rich education technology tools across the System and prioritize which additional data sources should be integrated into the ecosystem; the true power of learning analytics is in pulling disparate data sources together to allow a more holistic, directive profile of a an individual student.

The UWS LATC is, technically, currently available to all campuses using Learn@UW Utility instance of D2L. Unfortunately, UW-Milwaukee, having its own learning environment data store and learning analytics data warehouse, can currently only access S3 and Pattern (since it is non-LMS dependent). For a modest development investment, that could easily change. Additionally, while the LATC is technically available to all campuses, there are some operational scaling issues with the underlying infrastructure—the largest being that data imports from the learning environment into the learning analytics data warehouse are still done manually by Learn@UW Utility. In order to scale more extensively, an investment would have to be made into automating this process. A final consideration for scaling is a wider culture of acceptance, interest, and practice of LA. While some System work has been done around this as part of the initial Growth Agenda Grant, a much larger investment is necessary in cultural events, training, support, and documentation.

VI. Appendices

Appendix A

About the UWS Learning Analytics Tool Chest

What is Learning Analytics?

Learning analytics is the measurement, collection, analysis, and reporting of data about learners and their contexts, for the purposes of understanding and optimizing learning and the environments in which it occurs.

~Society for Learning Analytics Research

Learning analytics can help faculty leverage the powerful data at their disposal to truly support a continuum of learners – from those at risk to those successful students that can be guided to greater heights. Learning analytics (sometimes abbreviated as "LA") can be successfully applied in large enrollment course where teachers wish to provide a more personal level of support but simply cannot because of the sheer size of the course.

Learning analytics can empower students as they progress through their academic career. They can monitor their progress and risk, get just-in-time cognitive scaffolds delivered at the moment of learning, find ways to alter their behavior and find the most effective help resources, develop personal learning networks, and explore effective paths to graduation and promising careers.

The UW System Learning Analytics Tool Chest

The UW-System learning analytics pilot program offers campuses and instructors access to several tools from the Learning Analytics Tool Chest (or "LATC"). Instructors may choose one or several tools to pilot for a semester. The Tool Chest currently includes: i) Analytics & Recommendation Plug-In (A&R), ii) Desire2Learn's Student Success System (S3), iii) Pattern, and iv) Workflow Visualization Tool (WVT).

Tools Matrix – Overview

Tool	D2L
Desire2Learn's Student Success System: Course-level predictive analytics tool with dashboarding and visualization.	X
Analytics & Recommendation Plug-In: Course-level tool that provides analytics of activity type within the LMS and recommendations for increased activity for higher (grade) performance. Instructors are able to see single, comparative and global analytics for all students within their course. A&R offers a student-facing dashboard.	X
Pattern: A quantified-self tool allowing students to track their study and learning behavior/activities, and subsequently rate their productivity. Acquired data then provides reports on most effective combinations for individual student efficacy.	n/a
Workflow Visualization Tool: The tool provides visual representation of course design, lesson plans, and individual activities, representing how an instructor intends students to interact with the course - and	X

then provides analytics on those activities.	

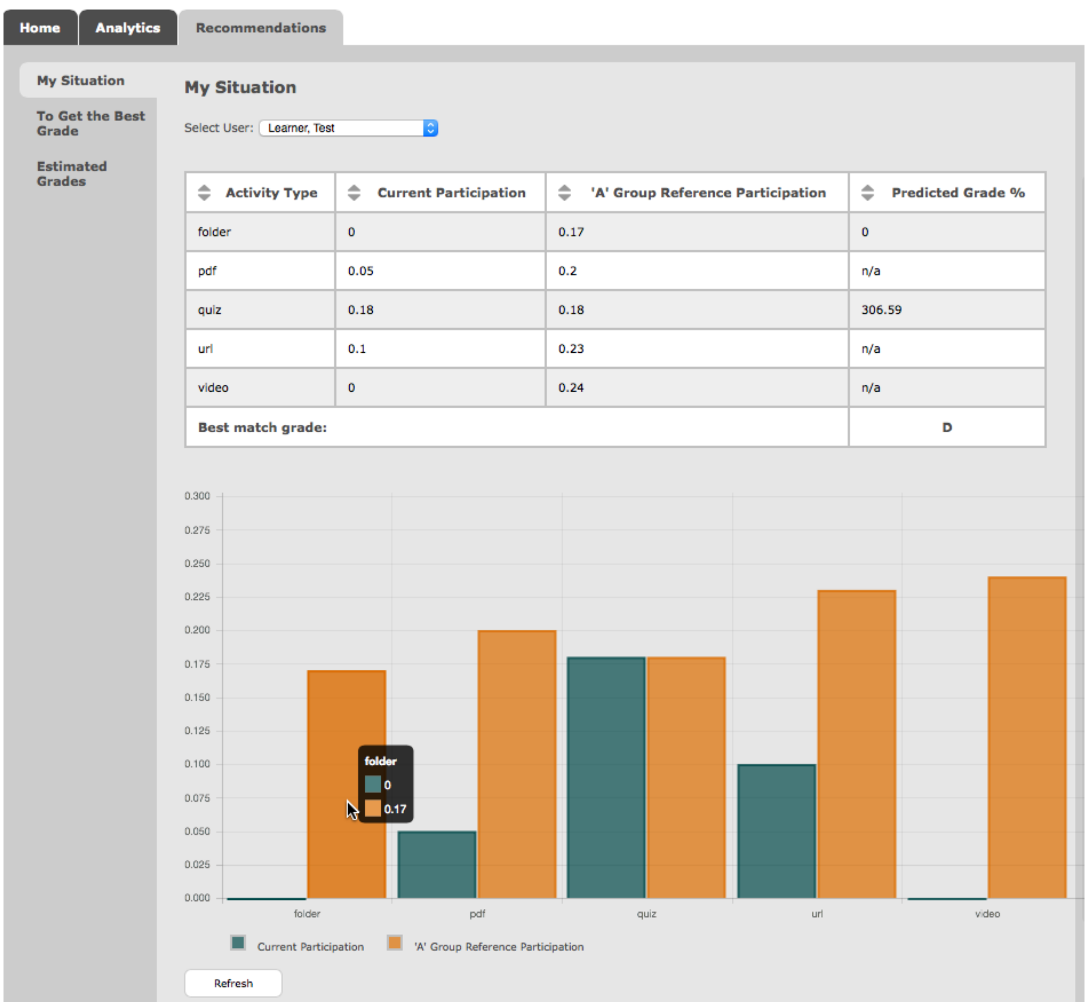
Analytics & Recommendation Plug-In

A&R Description and Features:

- A&R is a tool that provides analytics of various types of activities within D2L and provides recommendations for increased activity for higher (grade) performance.
- Instructors are able to see single, comparative and global analytics for all students within their course.
- A&R also offers a student-facing dashboard; it allows students to compare their participation in the course against high-performing students (in historical courses).
- It provides recommendations for where students should focus additional effort in the course.
- This is an open-source tool that has been leveraged and extended; it uses historical courses as reference courses (and is the most like Desire2Learn's Student Success System "S3").

Currently can be used with: D2L

Screenshot:



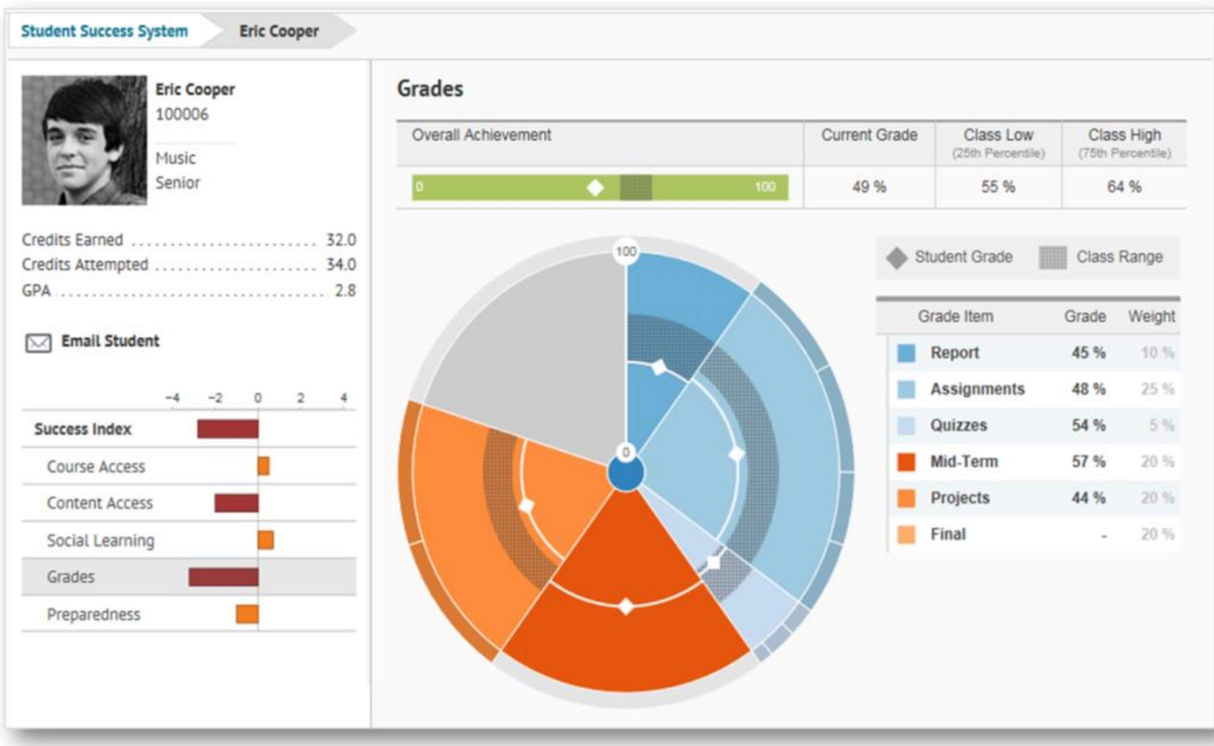
Desire2Learn's Student Success System or "S3":

S3 Description and Features:

- Course-level predictive analytics tool with dashboarding and visualization.
- Instructors use the Student Success System to monitor predictions of student success levels for active and enabled courses on a weekly basis in five possible domains: course access, content access, social learning, assessments, and preparedness.
- The weekly predictions produce a Success Index for every student in the course, letting you visualize and compare potential success rates for your students.

Can be used with: D2L

Screenshots:



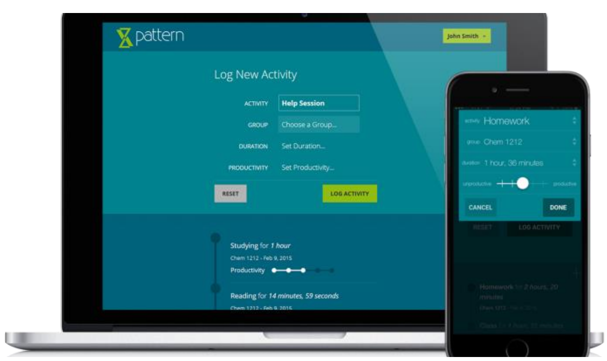
Pattern

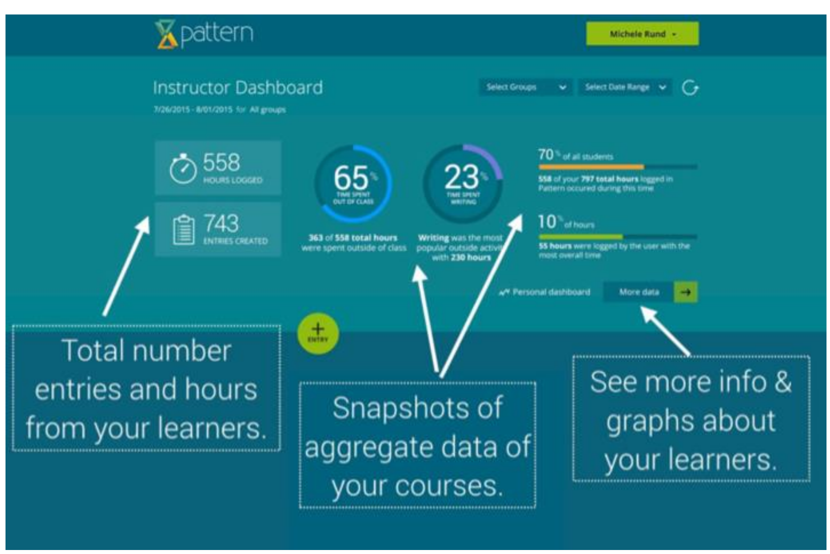
Description and Features:

- Pattern is an interactive study log (sort of like a FitBit for studying), and provides a simple way for students to measure their own study habits, providing analytics and insights to become a better learner.
- Students track their study and learning behavior/activities, and subsequently rate their productivity.
- Acquired data then provides reports on most effective combinations for individual student efficacy.
- Pattern is a mobile application that creates and curates data rather than relying on LMS data; this is the first tool in our Learning Analytics Tool Chest that moves out of LMS-centric tool space. Available for both iOS and Android devices, as well as a web app.
- Pattern allows us insight into holistic student behavior patterns. The data curated via Pattern may one day be ingested by other LA tools.

Can be used with: Pattern is a standalone application – it's not integrated with any LMS. It can be used for any course that might be offered in D2L, Moodle, Canvas, or without an LMS.

Screenshots:





Workflow Visualization Tool

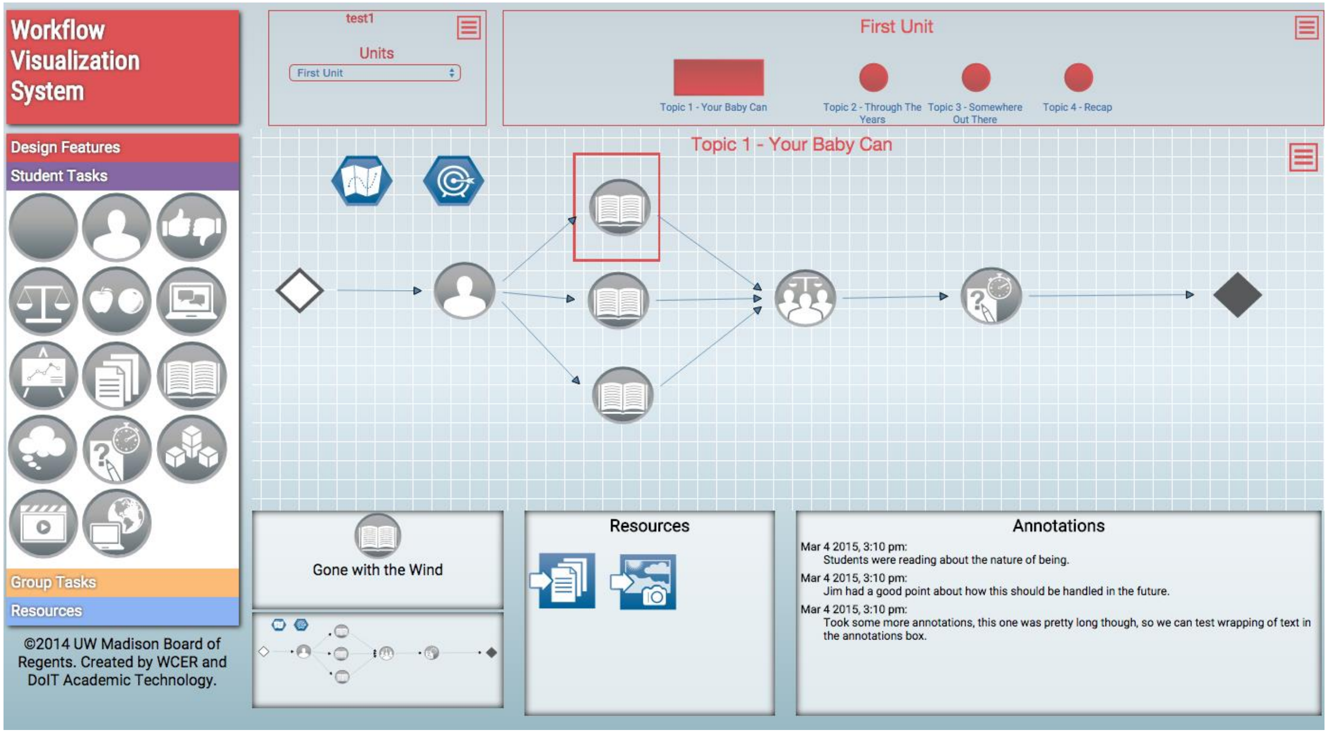
Description and Features:

The Workflow Visualization tool provides visual representation of course design, lesson plans, and individual activities, representing how an instructor intends students to interact with the course - and then provides analytics on those activities.

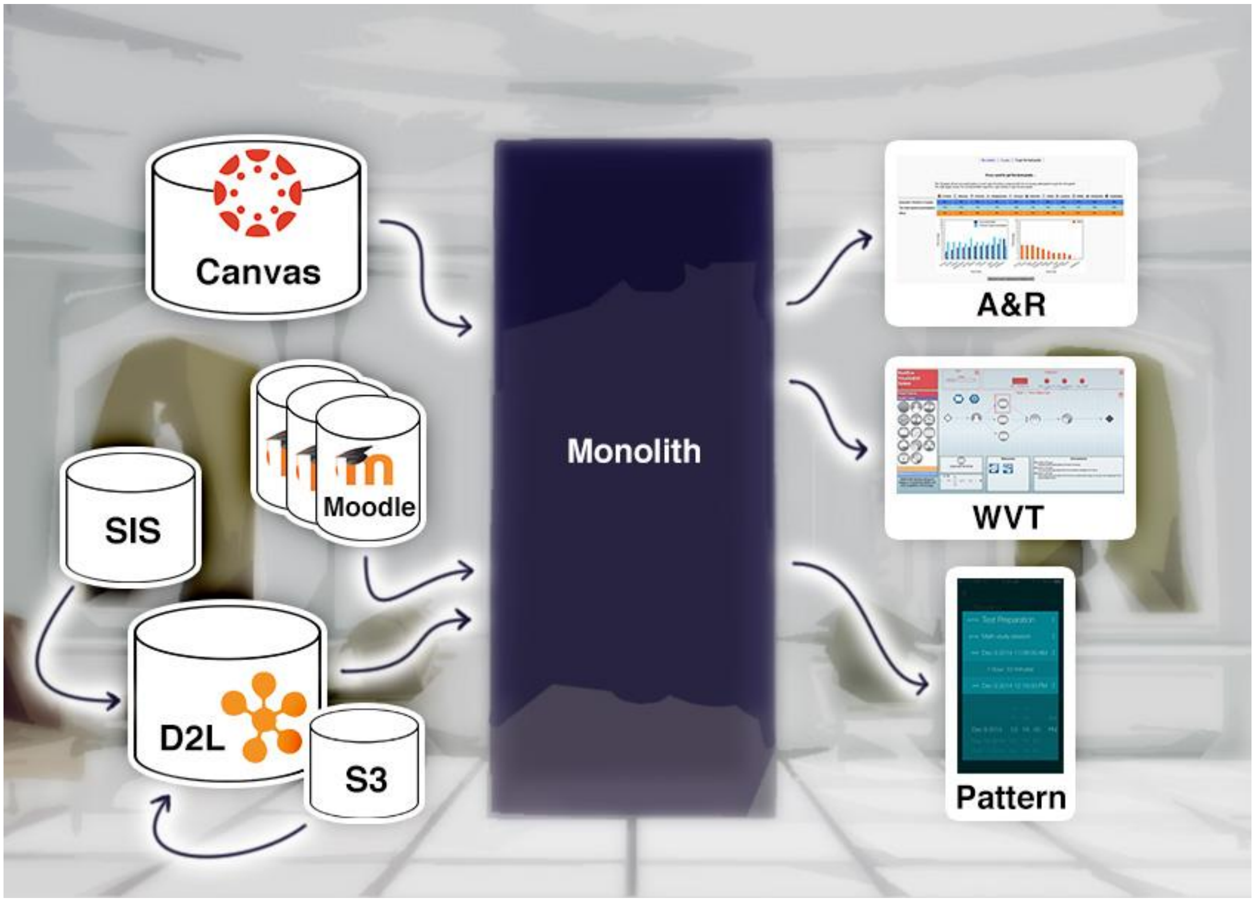
- Faculty have the opportunity to visually diagram their course – at the unit, lesson or activity level.
- This can then be linked to resources or activities within the LMS in a flexible way (not all elements will be in the LMS, or some activities may involve multiple LMS resources).
- Allows instructors to reflect on course design based on actual participation data (see how students actually navigated through activities and units as compared to how the instructor intended them to).

Currently can be used with: D2L

Screenshot:



Appendix B
Modularized System Designed for Learning Analytics Interoperability



Description and Features:
The Learning Analytics Tool Chest uses a Service Oriented Architecture (SOA) design to provide future flexibility and scalability. A services layer, internally known as "the Monolith" is used to keep the learning analytics tools decoupled from the actual data sources.

- Connections between the D2L data warehouse and two tools (WVT and A&R) are the only connections that are currently implemented.
- Moodle or Canvas connections could be implemented in the future, without necessitating change to the learning analytics tools themselves.
- Non-LMS data sources could also be incorporated into this model.
- Additional learning analytics tools could also be incorporated without needing to build new infrastructure to access data sources.

Appendix C
Proposed/Actual Budget

	Item Description *(person or item)*	**Proposed "Hours and Rate" (if labor) or "Purchase Cost"(if**	**Actual "Hours and Rate" (if labor) or "Purchase Cost"(if non-labor)**	**Proposed Budget**	**Actual Budget**
1	Data Extraction	5 hours @ $76/hr	7.5 hours @ $ 76/hour	$380	$570
2	Data cleaning, transform, and analysis	40 hours @ $68/hr	--	$2,720	--
3	Consultation for Algorithm Optimization	10 hours @ $84/hr	13.5 hours @ $76/hour	$840	$1026
4	Software Development	150 hours @ $84/hr	178.25 hours @ $76 / hour	$12,600	$13,547
5	Technical Project Management & Delivery	45 hours @ $76/hr	9.75 hours @ $63 / hour 21.25 hours @ $76 / hour 5.75 hours @ $84 / hour 2.5 hours @ $90 / hour	$3,420	$2937.25
6	*Remaining Budget being spent in late February – Invoicing is only complete through 2/20/16 and extension was granted*				$1879.75
		Total Request:		$19,960	$19,960
	Matching Funds (Source)			--	
1	DoIT Academic Technology (SME)	--	60 hours @ $84/hr	--	$5,040
2	UWSA - Learning Analytics campus coordination, documentation and testing.		70 hours @ $76/hr		$5,320
3	DoIT Academic Technology (Madison campus liaison) Software demonstrations, testing, troubleshooting with faculty.		80 hours @ $63/hr		$5,040
4	DoIT Academic Technology (D2L Admin) Desire2Learn administrative support and troubleshooting.		10 hours @/76		$760
		Total Matching funds:			$16,160.00

Appendix D
IPP Team Members

Kimberly Arnold, Learning Analytics SME/Algorithm Consultant
Doug Graham, Software Developer, TRAD
Dale X. Johnson, UW-Madison D2L Administrator
Stephanie Johnson, Portfolio Manager, TRAD
Kari Jordahl, UW-System Campus Coordinator
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Ian McNamara, Software Developer, TRAD
Brian Ploeckelman, Software Developer, TRAD
Garrett Smith, Software Developer, TRAD

The project team would like to thank the following individuals for support and guidance.

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Michael Merline, UW-Colleges Campus Liaison
Dylan Barth, UW-Milwaukee Campus Liaison
Dan Voeks, Service Leader, Learn@UW Enterprise Service
Lisa Bender, Linux Systems Administrator
Peter Burke, Learn@UW Application Administrator
Susan Degen, Learn@UW Support Specialist
Lori Docken, UW System Administration*
Diane Landry, Learn@UW Integration Consultant
Jeremy Maritz, Windows System Administrator
Lieven Milling, Windows System Administrator*
John Nagler, Learn@UW Application Administrator
Jennifer Schienle, Database Administrator
Andy Speth, Learn@UW Operations Lead
Steve Tanner, Windows Systems Administrator
Andy Taylor, UW System Administration*
Nick Terrible, Learn@UW Application Administrator
Xiujuan (Jane) Zhang, Learn@UW Integration Specialist*

Notes:

- Many individuals have contributed to the success of this project; the open source tools in the LATC have a present dependency on the D2L Insights infrastructure.
- *Provided support and assistance at various phases of this project; these individuals are no longer in the roles indicated here.