Designing Pedagogical Interventions to Support Student Use of Learning Analytics

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ABSTRACT

This article addresses a relatively unexplored area in the emerging field of learning analytics, the design of learning analytics interventions. A learning analytics intervention is defined as the surrounding frame of activity through which analytic tools, data, and reports are taken up and used. It is a soft technology that involves the orchestration of the human process of engaging with the analytics as part of the larger teaching and learning activity. This paper first makes the case for the overall importance of intervention design, situating it within the larger landscape of the learning analytics field, and then considers the specific issues of intervention design for student use of learning analytics. Four principles of pedagogical learning analytics intervention design that can be used by teachers and course developers to support the productive use of learning analytics by students are introduced: Integration, Agency, Reference Frame and Dialogue. In addition three core processes in which to engage students are described: Grounding, Goal-Setting and Reflection. These principles and processes are united in a preliminary model of pedagogical learning analytics intervention design for students, presented as a starting point for further inquiry.

Categories and Subject Descriptors

K.3.1 Computer uses in education

General Terms

Measurement, Design, Human Factors.

Keywords

Learning analytics, Intervention design, Student participation

1. INTRODUCTION

This article addresses a relatively unexplored area in the emerging field of learning analytics, the design of learning analytics interventions. As technology integration research has long shown, successful introduction of educational innovations is never simply a matter of providing access to new tools, no matter how useful [11, 16]. Without a plan for shifting patterns of teaching and learning activity, new technologies often remain ancillary to the teaching and learning process, either used tangentially to marginally enhance existing practices or often simply collecting dust on the virtual shelf [12]. If learning analytics are to truly make an impact on teaching and learning and fulfill expectations of revolutionizing education, we need to consider and design for ways in which they will impact the larger activity patterns of instructors and students.

A learning analytics intervention is defined as the surrounding frame of activity through which analytic tools, data, and reports are taken up and used. It is a soft technology in that it involves the orchestration of human processes, and does not necessarily require the creation of a material artifact (though one may be created to support representation or implementation of the process) [2, 22]. To date, most research and development in learning analytics has focused on the fundamental issues of data collection, management, processing and display, addressing the two core challenges of how to determine meaningful traces of learning and present them in a form that will be useful to decision makers [15]. However, as we enter a stage in which analytic systems are rapidly being rolled out for more general use, the design of the intervention surrounding activity with the analytics becomes a critical element for supporting the effective implementation of these tools. Specifically, learning analytics intervention design is concerned with addressing questions such as: when in the teaching and learning process should analytics be consulted (at what points, with what frequency); who should be accessing particular kinds of analytics (teachers, students, teachers and students together, instructional aides); why are they being consulted (what questions are they answering, how will this information be used); and most importantly, how the use of the analytics articulates with the rest of the teaching and learning practices taking place (what is the context for interpreting and acting on the information the analytics provide).

In this paper, I first make the case for the overall importance of intervention design and situate it within the larger landscape of the learning analytics field. I then move to specifically consider the issue of intervention design for student use of learning analytics, explaining why attention to students as users of analytics is valuable and why it is necessary to support students in this activity. The latter part of the paper presents a set of principles and processes that can be used by teachers and course developers to design pedagogical interventions that support the productive use of learning analytics by students. Finally, these principles and processes are united in a preliminary model of pedagogical learning analytics intervention design for students.

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2. LOCATING PEDAGOGICAL INTERVENTION DESIGN IN THE LANDSCAPE OF LEARNING ANALYTICS

The field of learning analytics is broadly concerned with how the collection, analysis and application of data can be used to improve processes and outcomes related to learning [21, 37]. While much initial work has necessarily attended to developing technical solutions to the challenges of data capture, processing and display, there is general acknowledgement that "analytics exist as part of a socio-technical system where human decision-making and consequent actions are as much a part of any successful analytics solution as the technical components" [41, p4]. As with all socio-technical systems, the various technical and social components are fundamentally interrelated, and thus success requires joint optimization of the whole [40]. In this vein, my focus in this paper is not on the technical aspects of extracting or presenting analytics (though clearly these are important elements of any effective learning analytics solution), but the elements framing how activity using such analytics is motivated and mobilized for productive use. I thus introduce the notion of *learning analytics interventions* as the organization of the human processes through which analytic tools, data, and reports are taken up as part of some larger educational activity. More specifically, as explained below, *pedagogical learning analytics interventions* are those interventions in which the educational activity expressly includes instructional, studying or other components such that the use of analytics has a direct and immediate impact on teaching and learning processes. Finally, the concept of *pedagogical learning analytics intervention design* then refers to systematic efforts to incorporate the use of analytics as a productive part of teaching and learning practices in a given educational context. Additionally, pedagogical learning analytics interventions can also be designed to be educative in nature [13] such that they help teachers and students to develop general understandings about ways that analytics can be helpful to their teaching and learning practices.

2.1 Classes of Learning Analytics and the Need for Pedagogical Intervention Design

Within the broad space of learning analytics, distinctions can be made between different kinds of analytics based on the types of data collected, characteristics users, and the kinds of decision making conducted [17]. At a macro level, administrators can use analytics as input for making programmatic decisions and to identify at-risk students. Often referred to as academic analytics [38], the data involved generally represents various high-level outcomes such as completion or overall achievement levels [8] and can be aggregated in various ways depending on purpose (i.e. student, class, department, institution etc.). Academic analytics involve relatively long time-cycles, using data from completed activities (courses, programs, etc.) to inform decisions about future ones. While the general notion of learning analytics interventions applies here, it is related to questions of workflow rather than direct teaching and learning processes per se; for example at what points in the administrative and advising process of an institution (or company) should analytics be consulted and how can this be usefully systematized as part of normal business practices. Such interventions are important for the use of analytics to support the educational enterprise in a broad sense, but would not be considered pedagogical in the sense described above.

In contrast, at a micro level learners and teachers using learning analytics are more likely to be interested in process data that can help them make better decisions about the learning event in which they are currently engaged [10]. In this case, the relevant data relates to tracking learning and an important element for interpretation and action is having a model of learning for the particular environment - i.e. a research-based framework for understanding what productive activity in the learning context looks like. In some cases the model may be specified such that analytics data is processed and interpreted according to some system of rules leading to automatic changes in the learning system [e.g. 32]. In other cases, data may be processed into categories according to a model, but then presented to stakeholders to support decision making [e.g. 23]. In a third situation, the data may be processed and presented in a manner agnostic to any particular model of learning and it remains to the user to make connections between the information provided and valued aspects of the learning activity.

In both of the latter two situations, several locally contextualized questions of interpretation and action arise, making the process of using the information provided by the analytics to guide effective decision-making decidedly non-trivial. First there is the question of making sense of the information that is provided; this involves basic issues of validity in terms of the appropriateness of inferences that can be made from particular data given the context in which it was generated and the ways in which it was processed. This inherently requires a theoretical component that explains what concept or construct the analytic represents and what its relevance and relationship to other concepts and constructs is hypothesized to be, since without such a mapping the measure does not have any meaning beyond itself [31]. Thus at its heart, interpreting analytics is a process of knowing how to ask useful questions of the data and find relevant answers [6, 43]. Practically this means that an analytics user must have an understanding of the pedagogical context in which the data was generated, knowledge of what particular analytics are meant to indicate, and an appreciation of how these relate to the learning goals of the situation [28]. During the interpretive process it is also important to keep in mind what information is not provided by the analytics, to avoid the danger of over-optimizing to that which can be measured at the expense of valued, but unmeasured entities [10, 15].

In addition to the conceptual task of making sense of the information provided by analytics, a second major challenge for analytics users is incorporating the process of interpreting and acting on analytics productively into the flow of learning activities. While this might initially be conceived of as a practical challenge, in fact it ties in to many of the conceptual questions described above in terms of over what time period is it valid to make certain kinds of inferences and when it is appropriate to take action on them. It also relates to the social dynamics of the learning environment in terms of who has the authority (and the responsibility) for particular kinds of decision-making at certain points in time, as well as how the use of the analytics can be made to articulate productively with (rather than fight against or exist in isolation of) the rest of the teaching and learning practices taking place. These kinds of questions, as well as the issues of interpretive frame described above, can be addressed and supported through pedagogical learning analytics intervention design.

2.1.1 Pedagogical Interventions for Teachers

Many of the core issues related to teacher use of learning analytics were recently reviewed by Lockyer and colleagues [28]. Their solution to the challenges of interpretation and activity flow was to align learning analytics with the process of learning design. This creates a unified cycle in which teachers document their pedagogical intentions through learning design, which then provides the conceptual frame for asking questions of and making sense of the information provided by the analytics [14]. Specifically, Lockyer and colleagues highlight the importance of identifying ahead of time what activity patterns would be expected for successful (or unsuccessful) student engagement in the pedagogical design, and using tools such as checkpoint and process analytics to look for these at particular points during the learning activity [28]. This is important because the same pattern of activity in a system may be considered more or less productive depending on the activity design; for example a wheel and spoke social network in a discussion forum may be appropriate for a Q & A session with an instructional expert, but problematic if the goal is to build community among a group of learners [5]. By addressing the questions of interpretive frame and activity flow, Lockyer and colleague's model describes a pedagogical intervention by which teachers can engage in systematic efforts to use analytics as a productive part of their everyday teaching practice [28]. Certainly other pedagogical interventions to support teacher use of learning analytics are also possible; however, this is currently one of the few models that has been described with any degree of specificity.

2.1.2 Pedagogical Interventions for Students

In contrast to teacher use, intervention design for students has received less attention; in many cases it seems to be assumed that simply providing well designed analytics will be enough to induce productive use. However there are several factors that work against this. One particular concern is that students are often not privy to their instructor's pedagogical intentions, and thus unaware of both the learning goals for an educational activity and what productive patterns of engagement in it (as indicated by the analytics) would look like. Another challenge for students is the strong metacognitive skills needed to use analytics as a tool for reflection and self-regulation [9]. While teachers may have had preparation or experience in being a reflective practitioner [34] students often struggle as self-regulated learners.

The challenges of comprehending pedagogical intent, recognizing productive patterns of activity, and activating self-regulatory skills suggest that on their own students are unlikely to know how or why to engage with analytics; but they also present opportunities for making students more active partners in managing their own learning. Specifically, how students participate in an educational activity can relate to their understanding of the activity and its purpose [26]; thus sharing pedagogical intent increases the potential for purposeful alignment between student behavior and instructional purpose. In addition, being proactively involved and engaged in directing one's own learning is thought to support better learning processes and outcomes more generally [4, 48], thus helping students to develop these as part of their use of analytics can have continued benefits in other academic areas, especially with the rise of more personalized modes of learning that place greater responsibility on the individual learner. Finally giving students the opportunity to be a part of directing their own course for learning can help the analytics serve as an agent of empowerment rather than enslavement.

In the context of these potential benefits, this paper specifically address questions about intervention design for student use of learning analytics and presents a set of pedagogical principles and processes that can be used by teachers and course developers to support the productive use of learning analytics by students. While the traces, analytics, and particular learning analytics intervention required in any given situation are specific to that context, a pedagogical model for framing interpretive activity by students can be described in terms of general principles and processes that can be applied to a variety of learning contexts.

3. PRINCIPLES AND PROCESSES FOR PEDAGOGICAL LEARNING ANALYTICS INTERVENTION DESIGN

As defined above, the pedagogical design of learning analytics interventions relates to the "soft" elements framing how activity using analytics is mobilized for productive use. This is a new area of inquiry; as such there is limited prior work directly addressing the challenges and opportunities for *learning analytics interventions* laid out above. Thus, the following principles and processes were developed as an initial framework to provide a starting point for design and research. This guidance was generated through a dialectical process, drawing on theories from education (specifically constructivism, meta-cognition, and self-regulated learning [e.g. 33, 36]), while considering the central analytics intervention questions of interpretation and action, as well as several more specific concerns such as transparency, rigidity/flexibility, and the hegemony of that which is measured [8, 10, 15]. This approach follows the tradition in the fields of both education and human-computer interaction of generating theoretically-motivated design models that can then be applied, tested, and refined iteratively [3, 39]. The model of pedagogical intervention design was also informed by our own process of iterative development in the initial implementation of a learning analytics application for online discussions [45]. Lessons learned through this design process included the power of dialogue to engage students and the lack of need for parity in how instructors and students interacted with the analytics. Data collected from the implementation is currently being analyzed, and will be used to provide further insight into the principles and processes. Validation of the model will happen over time as it is applied, adjusted and further developed by ourselves and others in the learning analytics community.

3.1 Principle 1: Integration

The principle of Integration is central to the basic notion of pedagogical intervention design. That is, pedagogical intervention design is about intentionally providing a surrounding frame for the activity through which analytic tools, data, and reports are taken up, while the principle of Integration states that this surrounding frame should position the use of analytics as an integral part of course activity tied to goals and expectations. This principle specifically addresses the challenge of helping students understand pedagogical intent and helps prevent against rigidity of interpretation by providing a local context for making sense of the data. It also supports the integration of analytics uses into activity flow of the learning environment. Finally, it provides an avenue for tailoring analytics use such that the same analytics suite can be useful in different ways in different contexts.

The basic idea of Integration is that the use of learning analytics needs to be conceived of as an element of the learning design itself, and that students need to understand these connections. This means that in planning a learning event, the instructor or learning designer must decide which metrics (of the ones provided by whatever system is being used) will be focused on in a particular situation based on the purpose of the educational activity, and identify what productive and unproductive patterns in these metrics are expected to look like. This planning stage connects to the notion of aligning learning analytics with learning design as part of the pedagogical intervention model for teachers discussed above [28].

In addition to choosing metrics and predicting patterns, there are two key additional elements of pedagogical learning analytics intervention design needed specifically for students. The first additional element is a plan for sharing the logic of connection between the learning analytics and learning activity with the students, so the thread between goals, actions and feedback is clear. This is conceptualized as a process of *Grounding* and is expanded on below in Section 3.1.1.

The second additional element is considering when and how it makes sense for the students to work with the chosen analytics in relation to the activity flow of the learning environment. In some cases (for example with learners experienced in self-regulation), it may be fine to provide students with context at the start of a learning experience and leave them on their own to decide when to integrate such use of the analytics into their individual learning processes. However, in many cases it can be helpful (or even necessary) to provide guidance to students about when the analytics might usefully be consulted. This can be put into practice through determining a schedule or timescale for checkpoints that makes sense for the activity at hand. The issue of temporal integration is discussed further under the processes of *Goal-Setting* and *Reflection* in Sections 3.2.1 and 3.2.2.

3.1.1 Process 1: Grounding

There are three elements that students need to understand in order to effectively use analytics as part of their larger participation in a learning activity: (1) the purpose of the learning activity, (2) the characteristics of what is considered productive engagement in the activity, and (3) how the learning analytics provided serve as a representation of this. These kinds of understanding can be developed in multiple ways. For example, depending on the parameters of the learning context (student maturity, class size, blended or fully online format, time available etc.) the goals of an educational activity might be simply presented and explained to students, or could be jointly determined by the instructor and students together. Similarly, the characteristics of productive engagement in the activity could be brainstormed and then finalized by the group, or simply supplied to students with a rationale. Both of these activities (which aim towards a shared understanding of purpose and process among teacher and students) are actually useful for supporting learners in engaging in desired ways in an activity even before the analytics are introduced and can reasonably be enacted in a variety of ways in both face-to-face and digital settings. In addition, there is a need to tie the analytics available to the agreed-on qualities of productive engagement; the depth to which the calculation details of the different metrics are explained and considered will vary depending on the level of students, time available and perceived value. In each of the elements described here there is a trade-off between efficiency of presentation and depth of student engagement, but regardless the goal of the grounding process is to develop a shared understanding about the qualities of productive participation in the activity as a context for interpreting the analytics.

There is one additional important point to be made here and that is that connecting the analytics available to the qualities of productive engagement is a useful exercise not only for students to see what metrics serve as indicators of, but also to highlight any qualities of productive engagement that may *not* be captured by the metrics. One important concern in using learning analytics is that the analytics alone will dictate how people engage in the learning activity and thus we can "become what we measure," even though the metrics only capture some aspects of the overall activity [10,15]. For this reason, it is important for students to be aware of what the analytics they are using do not capture. It is also helpful to use multiple diverse measures so no one analytic becomes the sole focus of attention [46].

To give a concrete example of what the principle of integration and process of grounding might look like, take the analytics system *Uatu* designed to visualize collaborative writing process in Google Docs [30]. The system continuously collects and stores edit and revision data about user contributions, changes in document size, and time from Google Docs in order to support formative assessment of collaboration between learners. The visualizations generated from the data base contain the document revisions as they occurred over time, presenting who made certain revisions, when the revisions happened, the size of the contribution, and the time spent.

Imagining a pedagogical intervention design for the use of this tool as part of an online post-secondary history course, the instructor might first introduce the purpose of collaborative writing in this context to develop content knowledge and understanding of the core issues surrounding the subject through continued expansion on key themes over the course of the term. She then could provide students with clear guidelines for what is expected and will be evaluated; for example, the frequency and size of the contributions, and the quality of the contributions. Finally, the analytics can be introduced in this context, with the instructor describing how the feedback visualizes the collaborative construction of the document and how it relates to the participation criteria. For example, the instructor might encourage students to add to the document by identifying or adding to a theme on a weekly basis as they move through the semester and give a sense of how much elaboration (size) she expects from each contribution. The *Uatu* system currently does not provide metrics for quality, so this would need to be discussed as an element important for the activity, although absent in the metrics. In situations where the analytic tool used does provide information about the content of contributions, this could also be discussed. In this manner, the analytics are introduced as information which has clear meaning in the context of this particular collaborative writing activity. In an alternate context, with other students, and another kind of writing activity, the same analytics suite could be productively motivated with a different intervention design.

3.2 Principle 2: Agency

Learning is an activity that needs students' proactive engagement in order to be successful [48] and one of the key attractions of learning analytics is the possibility to support the learner in actively taking charge of managing their own learning process

[20]. The principle of Agency is thus targeted at promoting learning analytics interventions that that support, rather than detract from, students' development and use of self-regulatory skills. This also addresses concerns about analytics being yet another master for students to serve, rather than a tool of empowerment. In thinking about student agency, there are two important elements to consider: first, agency in interpreting the analytics (what does the information provided mean, how does it relate to what is important to me in this situation); and second, agency in in responding to the measure (what actions will I take as a result of the information provided). These elements are each addressed through the processes of Goal-Setting and Reflection.

3.2.1 Process 2: Goal-Setting

In self-regulation, learners guide their learning process by setting goals and working actively to attain them [36]. Goals can motivate learners to put in greater efforts for anticipated self-satisfaction and also incite self-monitoring of their achievement. Self-set goals especially lead to higher self-efficacy which influences the amount of effort learners make and their commitment to fulfill the challenges [49]. However, learners need guidance to make sure they set up proximal and specific goals with a proper level of difficulty to enhance learning [35]. It may seem that this discussion is superfluous since after developing a shared understanding about the purpose of an educational activity and the qualities of productive participation, students would all have the same goal of maximizing each of these qualities. However such an assumption is overly simplistic since students always have the possibility to set their own goals for a learning activity; some in line with the instructional goals for the activity, others less so [9]. In addition, each student has a different starting place and skill set that they bring to their learning, so even to reach the same end-state they may each have different aspects of the learning task that require more attention than others. This suggests the need for multiple possible profiles of productive activity and improvement, rather than a single goal and path which all students must follow.

For these reasons, a key element of student agency in learning analytics begins with individual goal setting to provide a personalized context for sense-making of the analytics. By making personalized goal-setting an explicit and structured part of the learning activity, learners are asked to be purposeful in thinking about the stated activity goals, evaluating their own strengths and weaknesses, and setting specific and proximal targets to work towards. Importantly, the process of goal-setting should be tied to and follow from the introduction of the learning activity purpose and characteristics indexed by the learning analytics as described above in the Integration principle. In this way, learning analytics can support the generation of specific and proximal goals since they provide clear indices for target-setting.

The actual process of goal-setting does not have to take place directly within the learning analytics system; however there are several advantages to doing so, principally the opportunity to support initial goal-setting and the ease of continual reference when the analytics are being reviewed. These possibilities are illustrated by *nStudy*, a web-based toolkit designed to support learners in studying online content by annotating it (e.g. creating tags, notes, and terms with definitions) and linking these information objects together to build up concept maps and the like [44]. While efforts to develop learning analytics for the system are still in progress, *nStudy* already supports learners in setting goals through a form that prompts them for a description and provides tools for indicating importance, difficulty, target date, current state of completion. An instructor using *nStudy* in their teaching might structure explicit use of this goal-setting functionality into certain points in the term, for example requiring students to set goals at the start of each segment of the course. In using such a tool possibilities also exist for sharing information about the aggregated goals of the class as a whole. Whether this is beneficial or detrimental for goal-setting and learning remains an open research question. Goals notes in *nStudy* are also easily retrieved, updated and linked to other objects in the system. Once the analytics features of the system are made available, reports or a dashboard could also be linked to the goals notes, facilitating reflection on the analytic metrics in the context of specific objectives and purposes.

3.2.2 Process 3: Reflection

Once set, goals drive how students interact with educational materials and activities and the feedback the analytics provides becomes an important moderator for students to monitor and assess their progress towards their goals [27], as well as evaluate when the goals themselves need to be updated or revised. This collection of activities involves looking back at information about the learning activities recently engaged in and, as such, is a form of data-informed reflection. From a constructivist perspective, reflection has long been thought of as an essential part of constructing one's understanding; in turn, as one's understanding develops, reflection can also be used more effectively to support learning [29]. However, reflection has traditionally depended on the learner's own recollection of the activities they engaged in, which research has shown is not particularly good [42]. Thus learning analytics offer an important advantage in supporting the process of reflection based on more accurate data.

However, as with goal setting, students need support in knowing when and how to reflect on their analytics and take action based on them. This is particularly important because online activities that can happen at anyplace and anytime often happen nowhere and never [24]; conversely attention to constantly available analytics can draw away from engagement in the activity itself. Thus to support productive reflective activity, explicit time, space and guidance need to be provided for reflection on analytics.

Time can be strongly structured by making reflection a specific course activity itself, or organized more softly through suggested guidelines provided to students. It is important to provide analytical feedback fast enough to impact practice [7] but also on a scale for which the analytics make sense to examine in a particular context. Especially for analytics that track larger scale constructs, the time-frame over which the data is examined can dramatically affect the results [47]. The frequency with which the analytics are provided or accessed and with which reflective activity is engaged in will vary depending on the context, but the goal of setting up specific timing is to avoid overwhelming students or making them overly reliant or fixated on the analytics [8].

The notion of a dedicated space for reflection also supports the actual enactment of the process as well as storing learners' reflective trajectory so they can look back at their learning progress over time. With historical records learners are able to notice their improvement (or lack thereof), monitor their goals and obtain a larger picture of their engagement with the learning activity. A variety of technologies can be used to create reflective spaces; the most obvious choice is perhaps a blog format where learners can articulate, refine and reflect their thoughts, ideas and opinions by writing in a journal [18]; however a wiki can also be used effectively for this purposed [45]. Both blogs and wikis also provide for the possibility of interactivity among learners or between a learner and the instructor, and thus have the ability to turn the reflective journal writing into a collective or dialogical activity [1]. This topic will be addressed further under the principle of Dialogue below.

Finally, learners need guidance in the process of how to reflect. Much of this guidance can take the form of just-in-time reminders to look back at their goals, consider their previous analytics, and think about where they are making progress and where more effort is needed. Reflective guidance can also be seeded through specific reflection questions or a structured reflective process if desired. Another possibility is to integrate support for reflection into the analytics system or include analytics on the reflective process itself. Such an approach has been followed with the *EnquiryBlogger* system which supports reflective journaling by encouraging students to tag their entries with a set of valued learning dispositions (e.g. critical curiosity, strategic awareness) and then provides them with visual analytics reflecting these perceptions of their learning power [7].

3.3 Principle 3: Reference Frame

In addition to the two central principles of Integration and Agency, there are two other principles for intervention design to support the productive use of analytics. The first is the principle of Reference Frame. A reference frame is simply the comparison point to which students orient when they examine their analytics. Two reference frames have already been discussed in the course of this paper. The first is the theoretical patterns of activity described as productive by the course instructor, which serve as an absolute reference point for comparison. The second is a student's own prior activity, which serves as a relative reference point for comparison. Depending on the context of the analytics use, an instructor may choose to emphasize one over the other.

A third reference frame that can be used is that of other students in the course. Aggregated information about the performance of others students is often provided in analytic systems and can be powerful in showing a student where they stand in relation to others in the class [19] but can also have several potential negative consequences [46]. Thus how the reference frame of other students is positioned in an important element of pedagogical intervention design. Specifically the performance of others students can be useful as a motivating factor for low-performing students who may not initially realize how their efforts stack up against others; however this frame of reference can also lead to competitive behavior or be stressful and intimidating for some students. There is also a tendency for aggregated class statistics such as course averages to become targets for students, which may or may not be appropriate depending on the activity profile of the class. For example, at the beginning of a course when students are just figuring out the system the analytic patterns displayed may not be ideal or realistic targets to aim for. In addition, measures of the class's central tendency (particularly the average) may be overly influenced by the activity, or inactivity, of certain students. For example, recent work looking at student activity in massive open online courses showed that a substantial portion (40-80%) of the population who enrolled in the courses studied did so simply to "sample" the course [25]; in this case measures of central tendency would provide a false reference point at which to target one's activity.

Some of the issues described above can be addressed through careful design and refinement of analytic tools; for example processing data to provide aggregate measures for only similar kinds of students or providing aggregate measures of variance as well as central tendency. However, there is also an important role for intervention design to play in terms of helping students to prioritize the reference points of self, peers and activity goals as well as understanding the value and limitations of the peer reference points provided in a specific context. This information can be provided up front as part of the initial goal-setting process, during the course of the learning activity, or as needed through individual dialogue as described below. For example, the *Student Activity Meter* is a learning analytics system that provides learners with line charts, bar graphs, and parallel coordinate visualizations showing how they compare to their peers in terms of metrics such as time spent working, intensity of work sessions, and number of resources used [19]. This toolset inherently encourages use of the peer reference frame in interpreting the data, though the line chart also allow learners to see changes in their individual working patterns over time.

To support productive comparative activity while guarding against a detrimental competitive mentality, a pedagogical intervention for this analytic tool could take several different forms. In some courses external standards for expected activity can be given. For example, if it is known that there is a minimum number of resources that generally need to be consulted to be successful on a project, this figure can be highlighted to students from the start as an fixed guidepost by which to judge progress. Similarly, if the instructor knows that students tend to be more productive when they engage in a smaller number of intensive work periods (rather than many brief ones), then they can be encouraged to work towards a line chart pattern that includes periods of steep rise, rather than one that is simply higher overall. In cases where absolute indicators are harder to provide, a pedagogical intervention might focus on the personal reference frame, explicitly asking students to keep track of and set goals for their individual progress, or their progress with respect to the group. Another approach might focus on collective efforts, encouraging the class to use the analytics as a group diagnostic to help each other keep advancing together. An important aim in each of these intervention designs is to help students avoid the simplistic mentality of "more (than other students) is better." While knowing where one stands in relation to ones' peers is important and useful, in some cases more than others may still not be enough (generally or for that particular student), while in other cases everyone may already be well beyond the bar of what is necessary, making additional exertion to improve a particular metric wasted effort. If all students are always trying to surpass all other, it may even create an unintentional ratcheting effect.

3.4 Principle 4: Dialogue

An important issue in implementing learning analytics relate to questions of power and access to analytics [15]. The concerns related to these issues can be addressed to some extent through the principle of Dialogue; that is creating a space of negotiation around the interpretation of the analytics in which data serves as a reflective and dialogic tool between the instructor and students rather than one in which the instructor collects data on the students. This serves as a complement to the principle of Agency in which students are empowered to set goals for and reflect on their own analytics and also provides support for students in engaging in this process.

As mentioned above, many online journaling tools such as wikis and blogs support interactivity between individuals, thus a dedicated space set up for reflection can easily be made a shared space between student and instructor, or even between groups of students. For example, *EnquiryBlogger* discussed earlier as an example of a purposefully created reflective space, provides functionality for instructors (and other students) to access and comment on the blog entries and to search for ones tagged with specific learning dispositions [18].

There are several advantages to making the reflection process dialogic. First, a shared journal creates an audience for the writing and gives the student the opportunity for their voice to be heard. Specifically, students may be able to bring information to bear in interpreting their analytics that the instructor would not be aware of on their own (e.g. "I had a really difficult time with this part of the assignment," "I tried extra hard this week," "I know I need to share my ideas more, but I don't always feel confident that I have the right idea"). Second, it gives the instructor (or a designate) the opportunity to examine students' goal-setting and analytics interpretations and respond as necessary to address any confusions, repair questionable interpretations, or realign goals. Finally, in some cases students may identify goals based on their analytics but not know how to make progress on them, thus a dialogic space gives them the opportunity to ask for help and the instructor the chance to provide suggestions or strategies. In these ways interactive journal writing actively facilitates the process of reflection [1] as well as provide a checkpoint to make sure that students are on productive paths in their self-regulation. In addition, the analytics themselves provide a support for dialogue by acting as a third "voice" in the conversation. This gives the instructor a neutral object to which they can usefully refer in conversation (e.g. "did you notice how your level of participation compares to the rest of the class" rather than "you need to participate more").

The major challenge in enacting the principle of dialogue is the issue of scale. In a small class it is possible for the instructor to interact with all students on a relatively frequent basis, but as the student to instructor ratio rises this become progressively more difficult, and in the case of massive open online courses it is simply not possible. Two possible alternatives for fostering dialogue around analytics may be plausible, however. First, a tiered system could be employed where teaching assistants or student leaders serve as the primary dialogue partner, with questions or concerns elevated to the instructor as needed. Second, in some situations it may be viable for students to support each other through partnership or triad models. The concern here comes from a lack of experience on the part of the students and the ability to effectively support each other, thus this approach may work best with learners who are relatively proficient in using analytics to the support their learning.

4. CONCLUSIONS

This paper has made the case for the importance of pedagogical intervention design for student use of learning analytics and situated it within the larger landscape of the field. Four principles (Integration, Agency, Reference Frame and Dialogue) and three processes (Grounding, Goal-Setting and Reflection) for the design of pedagogical learning analytics interventions were introduced as tools for helping to support the productive use of learning analytics by students. As may be clear by now, the issues related to each of these principles are not independent, and in fact are quite tightly entwined. For example the process of reflection ties back to goals, makes use of a reference frame and is shared with the instructor as part of a dialogue, while integration to some extent serves as a meta-organizing principle that encapsulates all others. To represent these relationships, I present a preliminary model integrating the elements of pedagogical learning analytics intervention design for students in Figure 1. This model is offered not as an end point, but as a starting place to stimulate attention to learning analytics intervention design. Empirical work is needed to apply, test, validate, refine and revise this model and develop our understanding of other factors that can support the productive use of learning analytics by students. As discussed above, in my own research group we have already collected data from a learning analytics intervention for online discussions developed in consultation with the model. The data is currently being analyzed to provide initial empirical validation and further inform our understanding of the principles and processes involved. Further application of the pedagogical intervention design model in other kinds of educational contexts with different learning analytics applications and populations of learners is needed to establish its more general utility and identify the additional considerations needed to usefully apply and adapt it across a variety of learning analytic contexts.

To conclude, this paper has taken an initial step towards the intentional and principled design of learning analytics interventions for students. Such attention to pedagogical intervention design is a critical complement to technical developments in order for the field of learning analytics to truly make an impact on the ways in which we teach and learn.

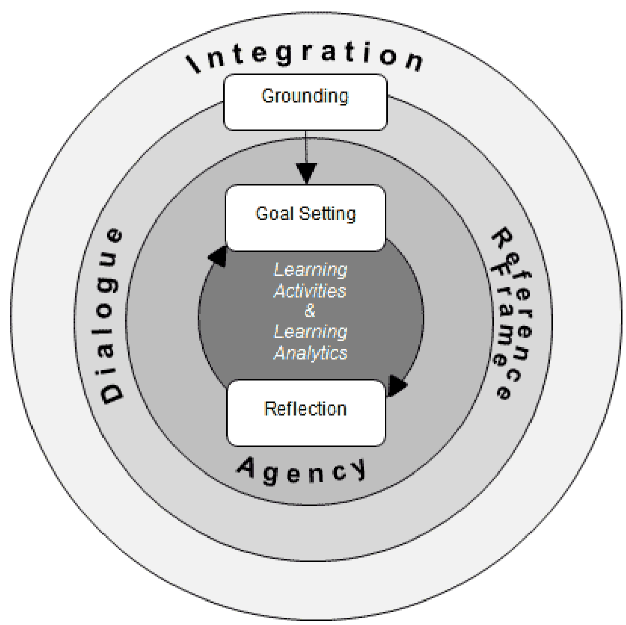

Figure 1. A preliminary model of pedagogical learning analytics intervention design.

5. REFERENCES

[1] Andrusyszyn, M. A., & Davie, L. 1997. Facilitating reflection through interactive journal writing in an online graduate course: A qualitative study. *The Journal of Distance Education, 12*(1/2), 103-126.

[2] Arthur, W. B. 2009. *The nature of technology: What it is and how it evolves.* Free Press, New York, NY.

[3] Barab, S., & Squire, B. 2004. Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13*(1), 1–14.

[4] Boekaerts, M., Pintrich, P. R., & Zeidner, M. Eds. 2005. *Handbook of self regulation*. Elsevier, London.

[5] Brooks, C., Greer, J. & Gutwin, C. In press. The data-assisted approach to building intelligent technology enhanced learning environments. To appear in J. Larusson & B. White Eds. *Learning analytics: From research to practice*. Springer, New York, NY.

[6] Buckingham Shum, S. 2012. Our learning analytics are our pedagogy. Keynote address given at *Expanding Horizons 2012*. Macquire University, Australia.

[7] Buckingham Shum, S, & Deakin Crick, R. 2012. Learning dispositions and transferable competencies: Pedagogy, modelling and learning analytics. In *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge* (Vancouver, Canada, 2012). ACM, New York, NY, 92-101.

[8] Buckingham Shum, S.& Ferguson, R. 2012. Social learning analytics. *Educational Technology & Society, 15*(3), 3-26.

[9] Butler, D. L., & Winne, P. H. 1995. Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, *65*(3), 245-281.

[10] Clow, D. 2012. The learning analytics cycle: closing the loop effectively. In *Proceedings of the 2nd International Conference on Learning Analytics & Knowledge*, (Vancouver, Canada, 2012). ACM, New York, NY, 134-138.

[11] Cuban, L. 1986. *The classroom use of technology since 1920*. Teachers College Press, New York, NY.

[12] Cuban, L., 2001. *Oversold and underused: Computers in the classroom*. Harvard University Press, Cambridge, MA.

[13] Davis, E. A., & Krajcik, J. S. 2005. Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

[14] Dawson, S., Bakharia, A., Lockyer, L., & Heathcote, E. 2011. *"Seeing" networks: Visualising and evaluating student learning networks.* Final Report 2011. Australian Learning and Teaching Council, Canberra.

[15] Duval, E. & Verbert, K. 2012. Learning analytics. *E-Learning and Education, 1*(8).

[16] Ertmer, P. A. 1999. Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development, 47*(4), 47-61.

[17] Ferguson, R. 2012. *The state of learning analytics in 2012: A review and future challenges.* Technical Report KMI-12-01, Knowledge Media Institute, The Open University

[18] Ferguson, R., Buckingham Shum, S., & Deakin Crick, R. 2011. EnquiryBlogger: Using widgets to support awareness and reflection in a PLE Setting. In: *1st Workshop on Awareness and Reflection in Personal Learning Environments*. In conjunction with the PLE Conference 2011, 11-13 July 2011, Southampton, UK.

[19] Govaerts, S., Verbert, K., Duval, E., & Pardo, A. 2012. The student activity meter for awareness and self-reflection. In *CHI'12 Extended Abstracts on Human Factors in Computing Systems*. (Austin, TX, 2012) ACM, New York, NY, 869-884.

[20] Govaerts, S., Verbert, K., Klerkx, J., Duval, E., 2010. Visualizing activities for self-reflection and awareness. In *Proceedings of 9th International Conference on Web-based Learning*, (Shanghai, China, 2010).

[21] Haythornthwaite, C., de Laat, M., & Dawson, S. 2013. Introduction to the special issue on learning analytics. *American Behavioral Scientist*, *57*(10), 1371-1379.

[22] Hlupic, V., Pouloudi, A., and Rzevski, G. 2002. Towards an integrated approach to knowledge management: 'Hard', 'soft' and 'abstract' issues. *Knowledge and Process Management, 9*(2), 90-102.

[23] Jovanović, J., Gaševic, D., Brooks, C., Devedžic, V., Hatala, M., Eap, T., et al. 2008. LOCO-Analyst: Semantic web technologies in learning content usage analysis. *International Journal of Continuing Engineering Education And Life Long Learning 18*(1), 54-76.

[24] Jun, J. 2005. Understanding e-dropout. *International Journal on E-Learning, 4*(2), 229-240.

[25] Kizilcec, R. F., Piech, C., & Schneider, E. 2013. Deconstructing disengagement: analyzing learner subpopulations in massive open online courses. In *Proceedings of the Third International Conference on Learning Analytics and Knowledge* (Leuven, Belgium). ACM, New York, NY, 170-179.

[26] Knowlton, D. S. 2005. A taxonomy of learning through asynchronous discussion. *Journal of Interactive Learning Research, 16*(2), 155-177.

[27] Locke, E. A., & Latham, G. P. 2006. New directions in goal-setting theory. *Current Directions in Psychological Science, 15*(5), 265-268.

[28] Lockyer, L., Heathcote, E., & Dawson, S. 2013. Informing pedagogical action: Aligning learning analytics with learning design. *American Behavioral Scientist, 57*(10), 1439-1459.

[29] McAlpine, L., & Weston, C. 2000. Reflection: Issues related to improving professors' teaching and students' learning. *Instructional Science, 28*(5), 363-385.

[30] McNely, B. J., Gestwicki, P., Hill, J. H., Parli-Horne, P., & Johnson, E. 2012. Learning analytics for collaborative writing: a prototype and case study. In *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge* (Vancouver, Canada, 2012). ACM, New York, NY, 222-225.

[31] Messick, S. 1989. Meaning and values in test validation: The science and ethics of assessment. *Educational Researcher, 18*(2), 5-11.

[32] Roll, I., Aleven, V., & Koedinger, K. R. 2010. The invention lab: Using a hybrid of model tracing and constraint- based modeling to offer intelligent support in inquiry environments. In *Proceedings of the 10th International Conference on Intelligent Tutoring Systems*. (Berlin, Germany, 2010). Springer, Berlin Heidelberg, 115-124.

[33] Savery, J. & Duffy, T. 1996. Problem based learning: An instructional model and its constructivist framework. In B. Wilson Ed. *Constructivist learning environments: Case studies in instructional design.* Educational Technology Publications, Englewood Cliffs, 135–148.

[34] Schön, D. A. 1983. *The reflective practitioner: How professionals think in action*. Basic Books, New York, NY.

[35] Schunk, D. H. 1990. Goal setting and self-efficacy during self-regulated learning. *Educational Psychologist, 25*(1), 71-86.

[36] Schunk, D. H., & Zimmerman, B. J. 2012. Self-regulation and learning. In I. B. Weiner, W. M. Reynolds & G. E. Miller Eds. *Handbook of psychology, Vol. 7, Educational psychology, 2nd ed.* Wiley, Hoboken, NJ, 45-68.

[37] Siemens, G.,Gašević, D., Haythornthwaite, C., Dawson, S., Buckingham Shum, S., Ferguson,R., et al. 2011. *Open Learning Analytics: An Integrated and Modularized Platform* (Concept Paper): SOLAR.

[38] Siemens, G., & Long, P. 2011. Penetrating the fog: Analytics in learning and education. *Educause Review, 46*(5), 30-32.

[39] Stolterman, E. & Wiberg, M. 2010. Concept-driven interaction design research. *Human–Computer Interaction*, *25*(2), 95-118.

[40] Trist, E. 1981. The evolution of sociotechnical systems as a conceptual framework and as an action research program. In in A. Van de Ven & W. Joyce Eds., *Perspectives on organization design and behavior.* Wiley, New York, 19-75.

[41] van Harmelen M. & Workman, D. 2012. *Analytics for learning and teaching.* Technical report. CETIS Analytics Series Vol 1. No. 3.

[42] Veenman, M. 2013. Metacognition and learning: conceptual and methodological considerations revisited. What have we learned during the last decade? Keynote address given at *EARLI 2013*. Munich, Germany.

[43] Verbert, K., Duval, E., Klerkx, J., Govaerts, S. & Santos, J.L. 2013. Learning analytics dashboard applications. *American Behavioral Scientist*, *57*(10), 1500-1509.

[44] Winne, P. H., & Hadwin, A. F. 2013. nStudy: Tracing and supporting self-regulated learning in the internet. In R. Azevedo and V. Aleven Eds. *International handbook of metacognition and learning technologies.* Springer, New York, 293-308.

[45] Wise, A. F., Zhao; Y. & Hausknecht, S. N. 2013. Learning analytics for online discussions: A pedagogical model for intervention with embedded and extracted analytics. In *Proceedings of the Third International Conference on Learning Analytics and Knowledge* (Leuven, Belgium). ACM, New York, NY, 48-56.

[46] Wise, A. F., Zhao, Y. & Hausknecht, S. (in press). Learning analytics for online discussions: Embedded and extracted approaches. *Journal of Learning Analytics.*

[47] Zeini, S., Göhnert T., Krempel L., & Hoppe H. U. 2012. The impact of measurement time on subgroup detection in online communities. In *Proceedings of the 2012 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining*. (Instanbul, Turkey). IEEE, New York, NY, 389-394

[48] Zimmerman, B. J., & Schunk, D. H. Eds. 2013. *Self-regulated learning and academic achievement: Theoretical perspectives* 2nd ed. Routledge, London.

[49] Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. 1992. Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal, 29*(3), 663-676.

6. ACKNOWLEDGMENTS

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