The Use of Models in Learning Design and Learning Analytics

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Abstract. The practice of Learning Design (LD) and Learning Analytics (LA) is analysed using two lenses. Firstly, it is argued that both LD and LA involve the making of models. All models involve idealisation, i.e. the simplification of something complicated to make it more tractable. Various educational actors generate idealisations of the system they are working in, but only a subset of these idealisations is embodied in LD and LA implementations. Secondly, LD and LA both change the way that the actors in education handle the complexity which they are faced with in their practice. This is analysed in terms of the cybernetic concepts of variety and black boxes. It is then argued that LD and LA implementations share a tendency to shift control to higher levels in the hierarchy, and that this has consequences for the autonomy of teachers and learners, and for the acceptability to users of LD and LA. Finally, some conclusions are offered which can help LD and LA to be implemented while addressing the common problems that have been identified.

Keywords: learning design, learning analytics, idealized model, variety, management, organization, pedagogy.

1 Introduction

The field of learning design (LD) has made a significant contribution to the modelling of educational processes. Nevertheless, neither the approaches nor the technologies of LD have been widely adopted, and it is a cause for concern that there is no clear understanding of why this is the case. This is an important matter for those who have put their efforts into developing LD applications, but is perhaps not of major significance to those beyond the field. However, this paper argues that the same factors that have constrained the use of LD are also present in the newer and closely related field of learning analytics (LA). The momentum behind LA from governments and national agencies (for example [1]), commercial providers (for example [2]) and institutions (for example [3]) is substantially greater than that which was given to LD at its peak. Consequently, the stakes are higher for LA, and, if the argument presented here is accurate, there are major practical implications for those promoting the adoption of LA, and for those who may find themselves coerced into using LA applications.

The arguments are built on an analysis of the theoretical and conceptual foundations of LD and LA, making use of the concepts of idealised models and variety. Reference is made to implementation projects where appropriate.
The broad outline of the discussion is as follows:

- The common ground between LD and LA is identified.
- The concepts of idealisation and variety are used to analyse the similar ways in which both fields function within the typical structures of education system.
- The implications for users of the organisational context of LD and LA are explored, and a tendency of both fields to empower higher levels of the management process is identified.
- Recommendations are offered to designers, which can mitigate the systemic challenges identified for LD and LA.

In the paper 'management' is often mentioned in the context of education, and it is worth clarifying what is meant by this. Among other things, the act of teaching involves knowledge of the curriculum, monitoring the state of students, and engaging with individuals and groups to build their understanding of the topic under consideration. All such aspects are described as 'teaching practice'. Teaching also involves activities such as dividing knowledge into curricular areas, establishing and managing cohorts, assessing teachers and courses, putting students into groups, scheduling sessions, deciding which students should attempt which certification, and so on. All these processes are described as 'management' of education, and they may be carried out by teachers and head teachers, as well as those who have the title 'manager'. In English speaking countries 'the education system' often refers to the national organisation and funding of educational institutions. However, here 'system' in the context of education, refers to the entities and interactions which the manager, as defined above, seeks to manage. The paper aims to describe underlying mechanisms which are applicable to both schools and higher education.

2 The Relationship Between LD and LA

The call for papers for the present special issue identified "a natural and synergistic relationship" between LD and LA. This synergy could be examined by focusing on the distinctions between LD and LA, and then considering the ways that they can work together to support educational processes (for a recent example of this approach see [4]). Such a discussion might well generate insight, but this paper proposes that it may also mask the many characteristics which the two approaches share. The aim here is to understand the common factors between them, with the expectation that experience of work in one approach will inform work carried out in the other. Much has been written about the definitions of both approaches and their boundaries, but the broad outlines are clear.

A cogent description of LD is provided by Koper in [5]. While this piece is in a book that principally discusses IMS Learning Design, Koper's introductory chapter deals with the general principals of LD. He writes that

> What a teacher believes about good teaching and learning is influenced by one or more sources. These are: prescriptions taken from instructional design theory; concrete examples of best practices; and patterns of experience. In each case we will call the representation of this knowledge *learning design knowledge*. [1, p.3] (p.3, italics in the original).

Koper argues, following Reigeluth, that design knowledge is best understood as "a set of rules that can be applied to the design problem" [1, p.5]. Koper adds that "the best solution depends heavily on the context of the course", and that "these rules are not meant to be deterministic but probabilistic". He identifies

> three categories of good rules: (1) those derived from instructional design theory, (2) those derived from best practices, and (3) those derived from patterns in best practices. [1, p.5].

Koper then goes on to summarise the structure of a learning design rule as:

> '*if* learning situation S (*and* value V)
> *then* use learning design method M (*with* probability P). [1, p.6]

A learning design is, therefore, an explicit model of the process whereby a learner can best achieve learning objectives, and this model is usually justified by a theory or by existing practice. Definitions of LD say little about analysis, but, nevertheless, analysis is implied if one is to choose between different sets of LD rules, and to decide if their use has been successful. In the case of adaptive or programmed learning approaches, LD makes extensive use of data analysis in proposing actions.

Turning to LA, there are many competing definitions, including from Siemens, focusing on optimising learning [6], and from the 2016 Horizon report, focusing on profiling [7]. For present purposes that offered by Arnold and Pistilli for the influential (if much critiqued) Signals project is succinct and to the point:

> Through analytics, large data sets are mined and statistical techniques are applied to predict which students might be falling behind. The goal is to produce "actionable intelligence" [8] p. 267.

According to EDUCAUSE the typical first step in LA is "extracting large amounts of historical data and preparing them for analysis" [9], and then looking for patterns which can be used to build a predictive model for learner outcomes that are deemed to be significant. This is usually done by applying existing algorithms that have been 'trained' by adjusting weights and biases to optimise the accuracy of the predictions which they generate. The outputs of the algorithms are 'actionable' in that they can be used to make recommendations to other computer systems, or to people, in order to optimise the learning process that has been modelled. LA may be deployed in dedicated applications, but often makes use of dashboards embedded into the systems used for delivering and managing teaching and supporting learning, for example the Moodle Virtual Learning Environment, and the SITS student information system [10], which is ubiquitous in higher and further education in the UK. Both Moodle and SITS are integrated with the Jisc Learning Analytics Architecture [11]. As LA matures, its integration into such systems is becoming increasingly complete.

LA and LD both create and implement models of learning processes: they identify desired outcomes for a designated learning process, and propose 'if – then' rules about how those outcomes are best achieved. Both involve the gathering and analysis of data generated by the learner. Both provide prompts or recommendations to teachers, learners, and managers. However, because LA models of learning processes are largely expressed in algorithms, the models are often not explicit, and may be protected by patents.

Seen from this perspective, much of the difference between LD and LA is a matter of emphasis. This is not an insignificant matter, as it determines where researchers and technologists place their effort, and presents opportunities for collaboration. For example, it is likely that those working in LA will have developed sophisticated algorithms and methods which could be of great value to LD. Similarly, the explicit and justified models of LD could help in making the actionable recommendations of LA more acceptable to teachers, while open learner models (see [12]) could support collaborative design of LA applications. Many interesting papers can be written about these valuable exchanges between the two approaches. Here, however, the purpose is to diagnose common problems, raising the possibility of common solutions.

Finally, in both approaches the main focus is on the description of activities. The data which is processed by LA is generated by learners activities, while the methods used are strongly influenced by activity streams [13]. It can be argued that the distinguishing factor of LD, compared with earlier approaches to technology enhanced learning (TEL), is that it gives learners' activity equal importance to curriculum content, and seeks to take into consideration the range and complexity of those activities (for example [14]).

3 Idealisation and the Modelling of Learning Activities

LD and LA both have a declared focus on the learner and on the optimisation of their learning, and both operationalise this focus by creating models. This section explores what is involved in making a model, and how this relates to LD and LA. The analysis makes use of the concept of idealisation, concisely described by Heidl:

> According to Frigg and Hartmann (2012, sect 1.1) an idealisation 'is a deliberate simplification of something complicated with the objective of making it more tractable'. They give the following examples of idealisations '[f]rictionless planes, point masses, infinite velocities, isolated systems, omniscient agents, and markets in perfect equilibrium. …
>
> Aristotelian idealisation is also known as the method of abstraction (Cartwright, 1989, chapter 5). It means to remove in a theoretical model all properties of an object that we do not consider relevant for the explanation of the phenomenon of interest. [5, p.164]

In both LD and LA such idealisation is carried out by means of models, which I define following Kühne's [6, p.2] summary of Stachowiak [17]. Taking a position which is aligned with Heidl's description of idealisation, Stachowiak[1] argues that a model needs to possess three features:

mapping feature: A model is based on an original

reduction feature: A model only reflects a (relevant) selection of the original's properties.

pragmatic feature: A model needs to be usable in place of the original with respect to some purpose.

All LD methods are clearly based on this kind of modelling of the learning process. LA depends on predictive statistical models, but the modelling process is often less explicit. The focus on modelling in LD can be seen, for example, in Agostino [18],

[1] Stachowiak's original is available only in German.

and Dalziel [19], while educational modelling languages, such as IMS LD [20], are presented as meta-languages with which representations of educational processes can be constructed. LD's modelling languages and models do not claim to provide a complete representation of the learning process, but rather to provide, in Frigg and Hartmann's terms (see above), 'a deliberate simplification with the objective of making it more tractable'. 'Tractable' in the case of LD implies making it possible to recommend or specify an activity to be undertaken. The activity may be, for example, a learning activity to be offered, a learning resource to be provided, a tool to be used, or an aspect of a learning process to which attention should be paid. The model is often deployed to support computerised orchestration of learning activities. This potentially valuable functionality is obtained at a price, that of removing from the model 'all properties of an object that we do not consider relevant for the phenomenon of interest', i.e. much of the detail of learners and the learning process.

An obvious question to ask about these models is 'do they work?'. In the case of LD, the question amounts to asking whether the implicit or explicit learning design rules adopted in the model do in fact work as anticipated. This is the approach taken by Carr et al. [21], who correlate learning designs with achieved learning outcomes.

For LA, Rienties et al. identify

> an urgent need to develop an evidence-based framework for learning analytics with which students, researchers, educators, and policy makers can manage, evaluate, and make decisions about which types of interventions work well, under which conditions, and which do not. [22]

Rienties and his colleagues propose the Analytics4Action evaluation framework to meet this need. Useful work has been done to investigate and enhance the effectiveness of LA models by the Open Academic Analytics Initiative, who

> Research the portability of predictive models used in academic analytics to better understand how models developed for one academic context can be effectively deployed by other institutions and overtime, be enhanced through open-source community collaboration [23]

These questions of whether LD and LA models perform as intended are undeniably important. However, this paper is not concerned with the degree to which the expectations of the designers of LD and LA interventions are fulfilled in terms of learning outcomes or testable predictions. Rather it analyses the simplification which both carry out in idealising the domain of education when building their models, and the consequences of this for users and their institutions.

4 Two Systemic Problems

In this section interactions between models of LD ad LA and the educational systems in which they are embedded are explored. As part of this discussion, the concept of 'variety' is introduced and applied to LD and LA.

4.1 The Limitations of Educational Models

The identification of appropriate educational outcomes and activities is highly contested, and consequently the definition of appropriate simplifications is also contentious. This is manifested in the constant critique of school and university qualifications, questioning if they are a true measure of learning having taken place.

Strategies for simplification make the management of education feasible, but they do not reduce the underlying complexity of education. Individual learners and groups of learners retain their own prior understandings, histories, and preferences. Consequently, as argued in [24], when applying educational plans in the classroom, teachers frequently find that they need to carry out revisions to the planned activities, either adjusting them in advance (to take into consideration local circumstances), or improvised (in order to respond as best they are able to the emerging needs of learners). These changes are in general either only partially documented and reported, or not documented at all, and consequently the regulatory apparatus of education cannot provide a full picture of the way in which educational resources are being applied. Indeed, if all details were reported, this would counteract the benefits which the simplification provides for managers.

These two factors do not imply that the instruments and processes of educational management are ineffective, or should be abandoned. Rather it is argued that

- the desired outcomes of education are often poorly specified, or left unstated (e.g. teachers' modelling of intellectual aspiration)
- the effectiveness of educational management in reaching desired educational outcomes (whether well specified or not) is entangled with the undocumented aspects of teachers practice and the social dynamics of the classroom
- educational managers are systemically unable to estimate the significance of teachers' practice, or learners' efforts, in achieving educational outcomes.

4.2 Whose Idealisation Informs the Model?

In any public education system there is a hierarchy of control, that is to say, actors at a higher level can exercise power over those below, but those below cannot exercise power over those above, except by stepping out of the hierarchy (for example by refusing to administer examinations, as has been the case in the struggle over testing in primary schools in the UK [25]). This hierarchy is reflected in the development of computer systems. These systems may be procured by one level of actors for their own use (for example to support the government in managing its funding of education institutions), or be procured by one level of actors for use by actors below them in the hierarchy (for example, institutional managers may provide a virtual learning environment for use by teachers and learners).

We have seen that idealisation involves the simplification of something with the intention of making it more tractable. Two questions then arise: whose view of the world informs the simplifications, and to what end? With regard to the idealisation of education systems, a great deal of practical research could be done to establish how specific systems are idealised in specific locations, and to cumulate some general principles. In the absence of such research, however, some insight may be gained by

considering the responsibilities of the actors in the education system. Table 1 offers an indicative comparison between levels, but these may shift somewhat for different education systems and age groups. At each level of the hierarchy, actors busy themselves with a discrete set of processes with which they seek to influence the system which they are responsible for. At each of these levels an idealisation is established, and each level is unlikely to know much of what happens at other levels, for reasons which we discuss in the following section.

Table 1. Comparative idealisations of education.

Actor	Indicative elements of the actor's idealisation of the education system
Government	Curriculum. Pedagogical methods. Funding models for the education system. Evaluation of institutional results. Quality assurance criteria.
Institutional managers	Staff performance. Timetabling. Organisation of cohorts. Pedagogic methods. Retention. Academic performance of the institution. Financial management of the institution. Institutional culture.
Teachers	Lesson plans. Classroom management. Mentoring. Interpretation of teaching materials. Adjustments of curriculum and materials to the needs of learners
Learners	Key material to be learned. Required amount of study. Level of personal skills. Communication requirements

4.2 Variety and the Organization of Education

Educational technology does not only aspire to enhancing the learning of individuals, it is also an intervention in the organisation and management of educational activities. It is proposed that the cybernetic concept of 'variety' is useful in understanding this aspect. This sub-section introduces the term, and how it can be applied to education institutions. In doing so it draws on a report written for Jisc by the present author [26].

The manager of an educational process, be it at institutional, regional, or state level, is unable to respond to every change which occurs, or even to notice them all. This is not simply because of lack of effort or personal capability, but rather because of the logic governing the exercise of control. From the activities of each learner and teacher in each moment of each activity emerge a huge number of combinatorial states, which are orders of magnitude beyond the ability of a manager to deal with. Beer defines *variety* as "a measure of complexity, the number of possible states of a system" [16, p.35]. In this Beer builds on early work by Ashby, who formulated the Law of Requisite Variety [17, p.207], generally stated as 'only variety can destroy variety'. This law tells us that a manager of a system can only exercise control if the number of states which the manager can take up is equal to the number of possible states of the system to be controlled.

The manager therefore needs a strategy for matching the variety of the system to be managed. There are two options. Firstly, the manager can reduce the number of states of the education system to which they will pay attention, a process known as 'attenuation'. Liber [29] identifies three strategies for simplification by means of which educational managers achieve this.

1. knowledge is reduced to a number of categories or subjects (mathematics, psychology, history, etc.) which are embodied in schools or departments
2. students are categorised into available subjects, and levels of study
3. subjects are reduced to a set of courses, each with a curriculum, a lecture programme, reading lists and so on, with performance measured by assignments and examinations. Students are restricted as to which courses can be done in which order, and timetables enable the whole to take place.

Other strategies are possible, for example peer teaching and assessment, but the three identified by Liber have special status because they are typically mandated by quality assurance mechanisms and inspection regimes.

The second option open to the manager is to amplify their own ability to deal with variety. For example, a card index or database can be used to keep track of the personal details and histories of all learners, which would be impossible for staff to hold in their memory. Delegation to people or computer systems is also a form of amplification.

In many respects, the same issues that I have outlined above are also to be found in the management of learners' activities by teachers. Teachers, too, are constrained by the variety equation. They cannot match the variety of all their learners' states as they carry out their learning activities, and so learners maintain some degree of freedom in their interpretation of teachers' instructions.

5 The Implications for LD

In this section LD is discussed in terms of idealisation and variety. If, as has been argued above, LD and LA share a common approach to modelling, then the insights which are identified for LD will also be applicable to the more recent tradition of LA.

Let us return to Frigg and Hartmann's 'deliberate simplification with the objective of making it more tractable'. The educational modelling languages which enable learning designs to be formulated, if adopted extensively in an institution, impose a judgement about which aspects of educational activities are worthy of representation, and how they should be represented. If orchestrated by computers, teachers are forced to follow the structures specified by the system, or to rebel and reject the systems which they have been asked to use. The systems which deliver the orchestrated learning designs are inspectable by management, who can establish if teachers and their classes have in fact been carrying out the tasks ascribed to them, and what the detailed results were. Similarly, teachers' ability to inspect learners' work is enhanced, because their activities are registered on the system. These features change the variety equation.

LD attenuates the variety of the managed system by standardising the representation of learning activities, and the range of factors related to those activities which are deemed worthy of note by managers. Equally, the manager's variety is amplified by the technology, which enables representations of learning activities to be gathered together, represented, and monitored. Moreover, new sources of information, which it was not previously feasible to gather, can be added, such as a summary of the

current completion rate for assignments in a class, or a comparative analysis of formative assessment results between classes.

The LD community has not been unaware of the potential disruption of power balances and the potential reduction in teacher autonomy which these management capabilities could generate, although this danger has not been expressed in terms of variety. As a result there has been substantial work carried out on providing learning design tools which are intended for teachers, including the present author's work on the Recourse editor [30]. The influential LAMS system is also a case in point [31], as is the on-going work around the Collage project [32] system.

Such tools have not achieved widespread adoption. The ability of teachers and learners to develop and procure systems is extremely limited, and so the systems that they use are developed and procured at higher levels. There is therefore a danger that computer-based LD systems will instantiate the idealisations of education prevalent at these higher levels, and impose those idealisations onto the activities at lower levels. This danger is mitigated by the fact that individuals in, for example, government may also have been teachers, and will certainly have been learners. This will allow them some degree of insight into the experience of other actors. Similarly, developers of applications may be driven by a desire to serve learners or teachers, and have adopted strategies such as collaborative design to seek overcome the mismatch of idealisations. A straightforward problem for such avowedly bottom-up initiatives is that an application which matches the idealised model of the education system that a budget holder is trying to manage will be much easier to sell than one which does not. There is, however, a deeper-seated problem, which can be exemplified through two Jisc funded projects.

The Phoebe Pedagogic Planner sought to "involve lecturers, tutors and teachers from across the spectrum of post-compulsory learning in all stages of the project" [33] acting as practitioner-informants and critical friends. Similarly, Phoebe's sister project, the London Pedagogic Planner (LPP), worked with lecturers in collaborative workshops, with storyboards on planning modules and sessions, and the observations of hands-interaction feeding into the design process [34]. Nevertheless, Laurillard comments

> The pedagogy planning tool is for lecturers' own use ... There is a concern, however, that the tool intended for lecturers' personal use may be taken over by managers as an administrative tool. It could be used in this way, with appropriate safeguards… [24, p.4]

Neither Phoebe nor the LLP achieved adoption, despite funding and a collaborative design methodology, a pattern which has been repeated on numerous occasions in the field. Laurillard's concern therefore needs to be taken seriously. The information generated by the LLP was primarily of interest to institutional managers, dealing with providing coherence in planning between courses, modules, and sessions, and with documenting and representing pedagogic plans. This information is essential to institutional management in making coordination and reporting more tractable in a data-driven institution. For lecturers, however, the benefits are marginal, in that they are offered support in using technology for a task which they can already carry out well enough, and at the cost of sacrificing flexibility, as discussed below.

Both Pheobe and the LLP are high level tools, and their systemic impact is clear. However, the same issues also apply to tools which are concerned with the design of individual learning activities. To the extent that these tools are implemented on

institutional systems, or paid for by institutions, then the information is inspectable by managers. The critical question is "Who is the beneficiary of the information generated by the application?". Unless the application responds to needs voiced by end users, and genuinely meets those needs, then then no amount of collaborative design will remove the concern that the system may be taken over by managers.

In retrospect, we can propose that in introducing LD models to provide support for teachers and learners, researchers were also making an intervention in educational management and upsetting the balance of power and responsibility in educational institutions. The idealisations of the educational process which are to be found in Recourse, LAMS or Collage are expressed in terms of courses, cohorts, tools, learning objectives and curriculum content, activity descriptions and task completion. These are, of course, important entities in education, but they are largely the idealisations that enable educational management to function. The practice of teachers focuses on other idealisations in managing their classroom and learners. For example, in line with Sawyer cited above [24], Tomlinson describes how

> ...teachers understand that by attending to human differences they can best help individual students address common needs... There is no illusion that a single lesson plan will work effectively for every learner… Rather, teachers who practice differentiation accept it as a given that they will need to create a variety of paths toward essential learning goals and to help students identify the paths that work best in achieving success [26, p.16]

A teacher will find little support for these processes in LD tools, which are almost all developed by educational institutions or the vendors who supply them. The idealisations of learning activities which they constitute, are, unsurprisingly, those of educational managers, and the benefits that they offered to them.

6 Teachers' autonomy

In the previous section it was proposed that LD had the potential to limit teachers' autonomy, and this section goes on to discuss these limits in more detail.

6.1 The Reality of Teachers' Autonomy

One might imagine that if teachers are instructed by their employers to follow policy, then they are simply forced to follow these instructions. To briefly establish that, on the contrary, teachers do have a degree of autonomy in teaching practice, take the example of policy on the teaching of reading. In the UK 'synthetic phonics' has been stipulated by the Department of Education, which claims that "Research shows overwhelmingly that systematic phonics (SP) is the most effective way of teaching reading to children of all abilities." Andrew Davies argues that the intention of the Government is to impose this approach on teachers, but that this intention is being thwarted by the resistance of teachers in the classroom.

> I cannot help but conclude that the defenders of SP currently influencing government policy, and the former Schools Minister Nick Gibb in particular, do want their approach applied universally and without distractions for a period, however much their strategies are

> sanitised by the intelligence and common sense of many teachers up and down the land. [28, p.12]

Davies is writing as a critic of Government policy, but proponents of the policy are also conscious of teachers' autonomy, which they see as a danger. Debbie Hepplewhite "one of the prime advocates of synthetic phonics and author of the Phonics International programme" [37] is reported as being outraged that teachers might be encouraged not to follow explicit instructions:

> What is extraordinary and very worrying is that some academics think that teachers should have the autonomy not to teach the alphabetic code, the link between sounds and letters, or to teach it less thoroughly or just teach it to some children. [37]

A similar adaptation of reading policy by teachers is to be seen in the USA. Grant [38] offers a study of the way that four teachers respond to reform initiatives in reading, writing and mathematics. Discussing policy on teaching reading, Grant reports that "All four teachers report reading the new Michigan policy and yet they made very different sense of it.". Their responses ranging from embracing new policy "for some profound changes in both her instruction and in her assumptions about teaching and learning reading", to incorporating a few changes in practice that "seemed tacked on" [30,p.173].

6.2 Learning Design and Teachers' Autonomy

If policy makers were justified in their confidence that the policies which they impose are both the best approach that can possibly be deployed, and also equally applicable to all learners, then the only question at issue would be how these policies can best be enforced. If, however, the policies are at best approximations to the optimal approach, and have varied success according to the context in which they applied, then the maintenance of teachers' autonomy is essential both for learners and to teachers' professional well-being. There is reason to believe that the latter is the case. Firstly, an argument from first principles can demonstrate the lack of certainty inherent in teaching and learning. For example Edgard Morin argues in this way, concluding that "Learning is indeed an uncertain adventure which in itself permanently entails the risk of illusion and error" and that "the worst illusions are found within intolerant, dogmatic, doctrinaire certainties" [31, p.44]. Secondly the history of educational theories and policies shows that those certainties that are accepted are soon replaced by others which make opposite recommendations. For an exhaustive study of the varying approaches to our example of reading policy, see Smith [40]. The oscillating nature of policy is well indicated by Nichols, who points out that

> the Ancient Greeks instructed children with letters and sounds. The pendulum was at the phonics end. Horace Mann in the 19th century advocated the whole word approach. … In the 80's educators rebelled against contrived phonics work sheets, riding the pendulum back towards meaning in whole language. [41]

Policy is both necessary and desirable in educational management. But, for both the above reasons, it is wise to treat claims of certainty and universality with scepticism, and to value the autonomy of teachers in applying policy to their own context. From this perspective, LD offers a method for specifying the way that teaching should be carried out, and, to that extent, it offers a way of reinforcing top-down control of teaching activities by policy makers. It is not argued that LD has in

fact led to a reinforcement of authoritarian educational policy, LD has not had sufficient adoption by governments and institutional managers to be able to bring this about. But it is proposed that teachers resist the extension of control which LD can be seen to imply. For it is the case that some explanation is required for teachers' resistance to adoption. An earlier paper with colleagues [42] explored whether it was the difficulty of understanding modelling concepts which was the barrier to adoption, and it was found that it was not. The finger of blame was then pointed at the complexity of implementations, but repeated attempts to simplify implementations have not succeeded in achieving adoption, despite extreme efforts to simplify the interfaces, as explained in other work with colleagues [43]. Emulating Conan Doyle [36, p.111], having eliminated the impossible, whatever explanation remains is, if not necessarily the truth, at least a valid working hypothesis. And the last explanation standing is that resistance to adopting LD is related to teachers' autonomy.

Those who have worked with LD over the past 15 years may by this point be objecting that the field is being presented as oppressing teachers, when its intention is precisely the opposite: to provide computational support for teachers in making appropriate use of the widest possible range of pedagogies. Moreover, it has been widely recognised that, as the present author wrote in 2005, "there is a need for high-level tools which enable authors to define learning designs in terms of their own pedagogic skills and experience", and a great deal of effort has been spent in developing high quality applications of this sort. Indeed, all this is true, but does not contradict the argument being made here: that despite the best intentions, the idealisation and variety management inherent in LD is a threat to teachers' autonomy.

6.3 Learning Analytics and Teachers' Autonomy

The argument concerning idealisation and variety made for LD above, can also be applied to LA, perhaps with still greater force. But first we need to establish more clearly that the methods of LA are equivalent to the pedagogic models of LD. According to McCullagh, a 'statistical model' is constituted by a "set of probability distributions on the sample space" [45]. Applying Stachowiaki's criteria for model, above, such a distribution in LA is 'based on an original' (i.e. the learner), and 'reflects a (relevant) selection of the original's properties, and can be used in place of the original in what McCullagh refers to as an "inferential universe" [37, p.1231]. Thus, it seems clear that the statistical methods of LA constitute idealised models as I have defined them above, and are not simply referred to as models by linguistic convention. The argument made about idealised models and LD can therefore also be applied to LA.

Like LD, LA set out to support learners and teachers. This was set out by Siemens [6], when he foresaw that the field would generate insight into, for example, networks among learners, and concept formation among learners. In [6] Siemens also sought to distinguish LA from 'academic analytics' which would concern itself with the issues at the institutional level, such as learner profiles. As time has gone on, however, this distinction has become ever more blurred. In 2013 Siemens recognised that teaching and learning analytics were a strategic resource for the institution:

> It is envisaged that education systems that do make the transition towards data-informed planning, decision making, and teaching and learning will hold significant competitive and quality advantages over those that do not. [46]

Similarly, the current Jisc Effective Learning Analytics programme defines LA as meeting the challenge of "using data and analytics to support students; improving satisfaction, retention and graduation rates" [47]. Student satisfaction, retention, and graduation rates, while no doubt important to students, are also key strategic factors for university administrators and managers. It is therefore not a surprise that the implementation of LA has been largely driven by the needs of institutional management, particularly for issues such as retention, for example see [48]. Indeed, the first point made in Jisc's briefing on LA and student success is that "an increasing number of studies using control groups that show that retention and other measures of student success can be positively influenced by the use of learning analytics" [49]. These capabilities directly address the idealisations and related variety management equations of managers.

It should be recognised that some LA researchers have long sought to provide a counterbalance to the institutional control of LA applications, by investigating the way that teachers and learners can configure and make use of LA systems. A special issue of the British Journal of Educational Technology in 2015 was dedicated to showing how pedagogical design, inquiry and analytics can work together to form a virtuous circle [50], with papers exploring, for example, how scripting can be combined with monitoring of analytics to support teachers in designing and managing CSCL scenarios [51]. Similarly, Kennedy et al. report on work carried out by the Australian Government Office of Learning and Teaching to investigate and support ways in which learning analytics data could be more usefully harnessed by academic teachers in higher education. [52]. Van Leeuwen [53] investigates in detail the way that teachers can make use of LA in their teaching. She notes, however, that this work remains on the margins of LA: "While many articles describe the technical underpinnings of LA tools, not many empirical studies have been conducted yet to study whether and especially how LA can support teachers while regulating students' learning processes" [53], p.139. A smaller amount of similar work has been carried out to explore how learners can benefit from LA, see for example Wise's arguments for the importance of designing LA for student use [54], or Harrer for a proposal on learner centred visualisations. A recent paper by Kitto et al. [55] provides a thorough analysis of the challenges raised in the design of student-facing learning analytics, and offers two sample patterns which these challenges could be addressed.

However, with the exception of a discussion in [55], p.154, none of this valuable research into the ways that teachers and learners could become the principal actors in LA addresses the way that LA systems are developed, purchased and configured by technologists, educational managers, and companies. Nevertheless, these are key factors in determining the relationship between LA and teachers and learners. There is more extensive policy support for LA than there has been for LD, e.g. [56], and greater financial commitment made to LA by companies such as Pearson, e.g. [2]. It may be argued that these drivers have contributed to the practice of LA being still more deeply entwined with institutional management of educational processes than LD, and that the ability of teachers and learners to shape the technology is reduced to a similar extent.

6.4 Comparative impact on teacher autonomy

As I have discussed above, LA has much in common with LD, but there are typically differences in the relative strength of their common characteristics:

- The relatively detailed models of learning processes produced in LD are, in LA, often reduced to a set of indicators.
- The analysis of data generated by learner activities, which is an important part of the adaptive learning and programmed learning aspects of LD, is hugely expanded in LA.
- The location of budgetary control is also more significant for LA than for LD, because the costs of an LA programme are usually much larger than those required to experiment with LD.

Consequently, the problems which have been faced by LD, and which I identify above, are amplified in LA. The greater conceptual simplicity of LA learning models based on correlations, and their integration with institutional systems, make it more likely that LA will be imposed across an institution. Similarly, the alignment between the indicators used in LA, and the Key Performance Indicators (KPIs) used in personnel management, makes it easier for those simplified learning models to be enforced. This increases the attenuation of classroom activities as they are presented to those seeking to manage them.

At the same time the expansion of the collection of data from users, enables the black box of classroom activities to be made more transparent, and its contents to be processed and then inspected through dashboards. This amplifies the ability of the manager to cope with the variety generated by the classroom. It should be noted the same person may be both the manager and the managed in different contexts. The performance of the teacher in the classroom may be represented on dashboards to their head of department at the same time as the performance of the learners is represented to that teacher. The teacher may wonder if what has been gained outweighs what has been lost.

These two shifts in the variety equation both increase the power of those seeking to manage educational processes, and decrease the power of those seeking to enact their professional practice in responding to the emerging needs of their students. In simple terms, top-down interventions are favoured, while bottom-up interventions are suppressed.

7 Unexamined Models

The application of idealised models raises particularly complex issues in the field of education. The following section discusses these issues, in terms of conflicting idealisations and the interactions of ‘black boxes’.

7.1 Explicit and Obscure Idealisations

It may be objected that the descriptions of LD and LA provided above are themselves idealised models, which set aside much of the complex detail of the history of the two methods. And so they are. Idealised models are a core component of the scientific process, and need no apology, either from the present writer or from other implementers of LD and LA. Similarly, variety, and its management, is omnipresent, and any manager of any system will be forced to deal with it.

In this paper, the idealised models which have been used to construct the argument ignore many of the efforts that have been made to overcome the problems of unenthusiastic users and lack of adoption. In these efforts researchers and developers have often made interventions which run counter to the general trends that have been identified. If taken into account and discussed, the result would be a much more nuanced view of both LD and LA, but would also make it harder to identify underlying problems experienced by both fields. The present intention is to make tractable the diagnosis of a hypothesised underlying mechanism that generates connected problems in LD and LA; a mechanism which is otherwise hard to identify because it is encrusted with the complex details of the histories of the two fields.

The simplifications carried out in LD and LA, however, are not usually made explicit. Indeed, this is a frequent problem in education as a whole. To go back to our example of reading policy, the proponents of synthetic phonics appear reluctant to entertain the possibility that their solution might be an idealised simplification [37], perhaps because this could undermine their practical efforts to improve the lot of children, as they see it. It may also be argued that the idealisation in LD and LA is often invisible to developers and users, who are only aware that there is an intractable problem which they are seeking to describe in a way which facilitates its solution.

7.2 Conflicting idealisations

Obscure idealisations may be found in many contexts, but education is a special case because of the degree of conflict between idealisations. If one is manufacturing, for example, concrete beams then it is easy to agree on the purpose of the process: to produce beams of predictable strength that will not break and kill people. This can be operationalised in terms of materials, tolerances, production processes, etc. There may well be differences of opinion about the trade-offs and costs involved, but it is generally possible to achieve a well understood agreement. In the health sector, where the purpose is more complex than in engineering, death rates provide a widely accepted desirable outcome.

In education, however, there is little shared agreement on what is being produced. The identification of ‘learning’ as having taken place is controversial, and self-reference is hard to avoid, because the instruments of education (examinations) are used to validate the processes of education. Moreover, ‘learning’, however that may be conceptualised, is not the only desired outcome of education, which is also expected to maintain national cultures, produce employable adults, develop personal discipline, and so on. As a result, different actors in education can maintain their own explanations of what makes the process successful. Governments may point to their

management of finance and curricula. Institutions may point to a positive school environment and inspiring leadership. Teachers may point at a sophisticated understanding of their learners, adaptation of materials, and sensitive classroom management. Learners may point to their own efforts to make sense of the whole undertaking. All these explanations will be associated with distinct idealisations, all will have some justification, and none will be complete.

7.3 In praise of black boxes

The competing purposes and explanations of education can be maintained because each level is uninspectable to those above it, due of the variety equation. Teachers do not really know what learners do with their homework, head teachers do not really know what teachers do in the classroom, and ministries of education do not know what really goes on in schools. Consequently, there is are levels of recursion in the system which present themselves to managers as a 'black boxes' [57], and within which management cedes control to the professional practice of teaching professionals. Throughout the 19th and 20th centuries jostling for power took place between learners, teachers and educational managers, in different ways in different places, see, for example, Tatto et al. [58] for a description of recent conflict in Mexico. In each context, an accommodation has been established between regulatory authorities, management, and teaching professionals: to a varying degree of exactitude, educational managers indicate the goals which teachers and learners should work towards, provide a framework for them to act within, and ensure that the results of their activity meet some minimum standards. The details of the learning activities are determined by the professional skills of teachers and the ethical integrity of both teachers and learners.

This lack of transparency, and the consequent inability to impose control, creates a black box that "allows us to operate while remaining essentially ignorant" [57]. It is this that provides the flexibility which teachers and lecturers need if they are to make effective interventions with learners, and which learners may need to cope with the pressures they experience. Indeed, the education system as a social entity is constituted and maintained by a complex array of interacting black boxes.

Within the black box in which teachers carry out their professional practice, much of what they do can be characterised as mediating between the strategies for simplification of management and the variety of the learners for whom teachers have professional responsibility. Similarly, within their black box, learners mediate between, on the one hand, the cumulated instructions of their various teachers, and, on the other hand, the requirements of their home life, social life, and their personal interests and curiosity. LD, and to a greater extent LA, open up the black boxes of education, and make their contents more easily inspectable, and tractable to managers. In doing so, they tend to constrain the flexibility available to teachers and learners.

Moreover, as Kitto et al. point out, LA tools "are often presented by different vendors as black box systems (Pasquale, 2015), and so do not allow teaching academics to engage with them in anything but a superficial manner." [55] p. 152. Thus, teachers and learners may be obliged to work with new systems that function as black boxes, while their own context becomes increasingly transparent.

The danger arises that inappropriately implemented LA will enable managers to insist that their idealisations and indicators take precedence over those of teachers practice. If this occurs, the delicately balanced web of black boxes in the educational system is disturbed, and the system then starts to malfunction in unpredictable ways. Consequently, when learners, teachers, and institutional leaders find that the black boxes in which they act are being prised open by technologies such as LD or LA, they are likely to resist, even if they are unable to formulate what exactly the danger is.

7.4 Surrogate Worlds

The criteria for success of LD and LA are couched in terms of the idealisations which they adopt, as is, perhaps, inevitable. If these idealisations are partial, and related to the viewpoints of particular actors in the educational process, as argued above, then a danger arises. The success achieved by an LD or LA intervention may be achieved through the application of an idealisation from a higher level in the hierarchy onto the activities conducted in a black box at a lower level. Malfunctions in that occur in that black box will only be visible to the managing system if the malfunctions trigger the data collection processes which have been put in place, which in turn depend on the managing systems idealisation of the problem. For example, if learners are falling asleep in their chairs because their teachers have been forced to increase study loads, this will not be detected by the LA systems currently in place. The danger is that managers will make interventions on a surrogate world, a world which stands in only a loose relationship with the lived experience of teachers and learners. In the surrogate world, the results may be excellent, but destructive processes may be underway that are invisible to the manager. This is a common problem, and may be proposed as the reason why the pendulum of policy swings so wildly, as in our example of reading instruction [41].

If LD is used to manage a surrogate world, then the result is likely to be that teachers will not use the system, either by benign neglect, or by active rejection. In LA, however, a surrogate world can be more easily imposed. This is because the data gathered in LA can feed into the monitoring of the strategic goals of the institution, and because the indicators used by management, for example KPIs, can be instantiated in LA. It is therefore possible that if learners and teachers are resistant to an LA intervention, they nevertheless find that they have no choice by to comply or risk the application of sanctions. This may lead to alienation, demotivation, and more malignant effects resulting from double binds (see [59] by the present author for an outline of how double binds can arise in education).

8 Conclusions and recommendations

Some theorists hold that the reinforcement of top-down control is inevitably negative. For example Freire sought education that was “responding to the vocation of persons as beings who are authentic only when engaged in inquiry and creative transformation” [44, p.84], and saw the top-down instruments of educational

management as preventing this practice. Be this as it may, this paper has not argued that one position in the educational hierarchy has superior insight or moral force. Nor has it suggested that LD or LA are intrinsically oppressive, undesirable, or without educational value. Rather it has proposed that LD and LA tend to privilege the idealisations of educational managers, and so also tend to upset the established balance between rival idealisations, and to intervene in the variety equations of the education system. If this argument is accepted, then what positive recommendations can be made to system designers to help them adjust for this tendency?

Firstly, the arguments presented in this paper should alert researchers and systems designers to be aware that the domain of education

- is composed of a complex network of black boxes whose multiple connections are obscure
- is occupied by distinct interest groups, who contend in personal, professional, and political capacities.

An LD or LA intervention is inevitably an intervention in these aspects of education, and will raise many confounding issues. This challenge should not be avoided by researchers, but rather embraced as the opportunity to generate results from their methods, and to conduct much-needed experiments.

Secondly, two questions need to be asked by systems designers: to whom is the functionality valuable, and what are the systemic implications of providing that functionality? An honest statement about the first question, and an explicit theory about the second, would facilitate design, and help to allay the fears of users. The discussion in this paper illustrates how an analysis of idealisation and of variety can help in achieving this.

Thirdly, LD and LA applications are inquiries. These inquiries will be welcomed to the degree that their designated users believe them to be relevant and constructive. This in turn requires that users' interactions with the application relate to their own idealised model of education, rather than to that of the procurers of the application, or that embodied in educational documentation. As discussed in section 6.3, much of the work on teacher or learner centred analytics concerns the presentation, contextualisation or use of data generated by models determined by higher levels in the hierarchy. This paper argues that such work will not resolve the problems of top-down implementation. Rather, teachers and learners, should be enabled to conduct their own inquiries by formulating and testing their own explicit models of how their practice works and how it could be enhanced. In moving away from the models generated by managers, however, designers and developers should be aware that they will engage in conflicts between stakeholders with unequal power, defending competing idealisations.

Fourthly, in order to understand the systemic implications of LD and LA, it is not sufficient for researchers to model only the entities and activities about which they are gathering and using data to describe learning. It is also necessary to model

- the entities and activities which contribute to maintaining the viability of the system, but which may not be considered to contribute to describing learning
- the interactions between the entities and activities which researchers are gathering data about, and those which they are not.

In carrying out this modelling black boxes should not be eliminated from the system, nor added to it, without making a conscious and well-informed design decision.

Fifthly, if alignment of applications with the needs and models of management is essential for the operation of the institution, then this should be explicit, along with any coercion which is applied.

Finally, this paper has discussed LD and LA in terms of their common factors at an organisational level. It would be valuable to supplement this with in-depth studies of the experience of users of both methods, for example making use of ethnography and phenomenology. Such studies would contribute to confirming or questioning the mechanisms proposed here, and might also demonstrate distinctions between LD and LA which are not evident in the perspectives used in this paper.

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