

BIG DATA IN HIGHER EDUCATION: An Action Research on Managing Student Engagement with Business Intelligence

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Abstract

This research aims to explore the value of Big Data in student engagement management. It presents an action research on applying BI in a UK higher education institution that has developed and implemented a student engagement tracking system (SES) for better student engagement management. The SES collects data from various sources, including RFID tracking devices across many locations in the campus and student online activities. This public funded research project has enhanced the current SES with BI solutions and raised awareness on the value of the Big Data in improving student experience. The action research concerns with the organizational wide development and deployment of Intelligent Student Engagement System involving a diverse range of stakeholders. The activities undertaken to date have revealed interesting findings and implications for advancing our understanding and research in leveraging the benefit of the Big Data in Higher Education from a socio-technical perspective.

Keywords

Big data, Student engagement, business intelligence, action research, higher education, socio-technical approach

1. Introduction

The advances in emerging digital technologies, such as Radio Frequency Identification Devices (RFID), have enabled organizations to develop innovative ways to intelligently collect data that may not be possible before. However, this leads to the explosion of data and unprecedented challenges in making strategic and effective use of available data. The concept of “Big Data” is emerged to describe the volume, variety, and velocity of the data generated with Information and Communication Technologies (ICTs). Business and society need to act swiftly for innovation and competitive advantages. Business Intelligence (BI) as a concept and technology has significant potential in transforming data from distributed and heterogeneous sources into an integrated enterprise view for supporting organisational decision-making, management and strategic planning

This public funded research project aims to utilize the value of Big Data with BI solutions in the context of Student Engagement tracking System (SES) in a UK university and explore the strategic use of the enhanced SES. The researchers involved have taken the action research method as it provides one potential avenue to improve the practical relevance of Information Systems (IS) research (Baskerville and Myers 2004). The research concerns with the organizational wide development and deployment of Intelligent Student Engagement System that involves a diverse range of stakeholders.

It has potentially profound impact on student behavior, student management, and evidenced-based decision making cross the university’s operational, managerial and strategic levels. Research to date has involved undertaking surveys, interviews and focus groups with existing and potential users of SES. The activities have revealed important findings and interesting implications for advancing our understanding and research in leveraging the benefit of Big Data in Higher Education through a organization-wide BI adoption and diffusion. Over last two years, this action research has given the researchers the unique opportunity to work with the key stakeholders and develop valuable insights into the issues related to the benefits, challenges and opportunities in utilising Big Data using Business Intelligence. The paper reports the findings on identifying and implementing users requirements for developing BI solutions. More importantly, the paper discusses the potential benefits and current challenges of big data in Higher Education Sector. It provides unique insights into issues related to addressing big data with BI solutions from technical, managerial and behavior perspectives.

2. Big data and Business Intelligence

Big Data is making big headlines, especially in the commercial sectors. However, Big Data is not a phenomenon just affecting large commercial companies. With the increasing amount of data being collected and distributed from internal and external sources, organisations of all types are now able to access to so called Big Data. There are many definitions of Big Data, but key concepts of Big Data are three “V”s:

1. Volume - data has increased from terabytes to petabytes and is encroaching on exabytes.
2. Velocity – refers to not only how fast we accumulate data, but also how fast some of the data that we already have is changing.
3. Variety – data is continually evolving; it is both structured and unstructured.

There are two important additions to above three “V”s in relation to the use of the Big Data:

1. Verification – refers to data verification and security
2. Value – Most importantly, has the big data being utilised to generate value of the insights, benefits, and business processes, etc. within an organisation?

Business and society are constantly seeking new technical and managerial approaches to making the best use of Big Data generated with advanced ICTs. For example. Big Data can be used for:

- Improved Customer relationship management
- New products
- New business models – e.g. real time customisation
- Better decision making and planning
- Enhanced management – “managerial revolution”
- Reduced costs and improved efficiency

The concept of BI was introduced as a result of the need to aggregate, synthesise and report the data into an enterprise view for supporting decision-making and strategic planning. Theoretically, Simon’s (1965) decision-making process model provides good understanding on the intelligence concept. From the ‘intelligence-design-choice’ phases of decision-making, the ‘intelligence’ phase is of particular importance as it precedes the other two phases. The

‘intelligence’ phase is whereby the business environment is examined and problem areas as well as opportunities are identified. Key activity involved in the ‘intelligence’ phase includes classification of the opportunity or problem. BI system can encompass applications such as data warehouses, data mining, data marts and On-Line Analytical Processing (OLAP). The main purpose of BI is to enable interactive and easy access to diverse data, enable manipulation and transformation of these data, and provide business managers and analysts the ability to conduct appropriate analyses and perform actions (Turban et al. 2008). It is argued that Business Intelligence should be an essential component for Big Data systems.

3. Managing student engagement in UK HEIs

Big Data can be a big asset for Higher education. For example, data can come from a range of sources including: Student data; Institutional Data; Environment Data; and Partnership Data. Kelly (2005) points out that HEIs collect a large amount of data and knowledge, but individuals who work for HEIs cannot find an effective way to manage and utilize the information. With higher education institutions facing increasing pressures from social and economic change, student acquisition, engagement and retention becomes more critical than ever. It is believed that the success and development of university students has less to do with what they contribute or where they study but what they do during the course of their study as a student (Kuh 2001; Trowler 2010). Therefore, student engagement is viewed as an important antecedent to student learning and achievement, as well as to institutional success. Trowler (2010) conducted a thorough literature review on student engagement for The Higher Education Academy. Coates (2010) argues that student engagement is useful for managers because by monitoring student engagement, institutions can identify areas of good practice as well as areas for improvement.

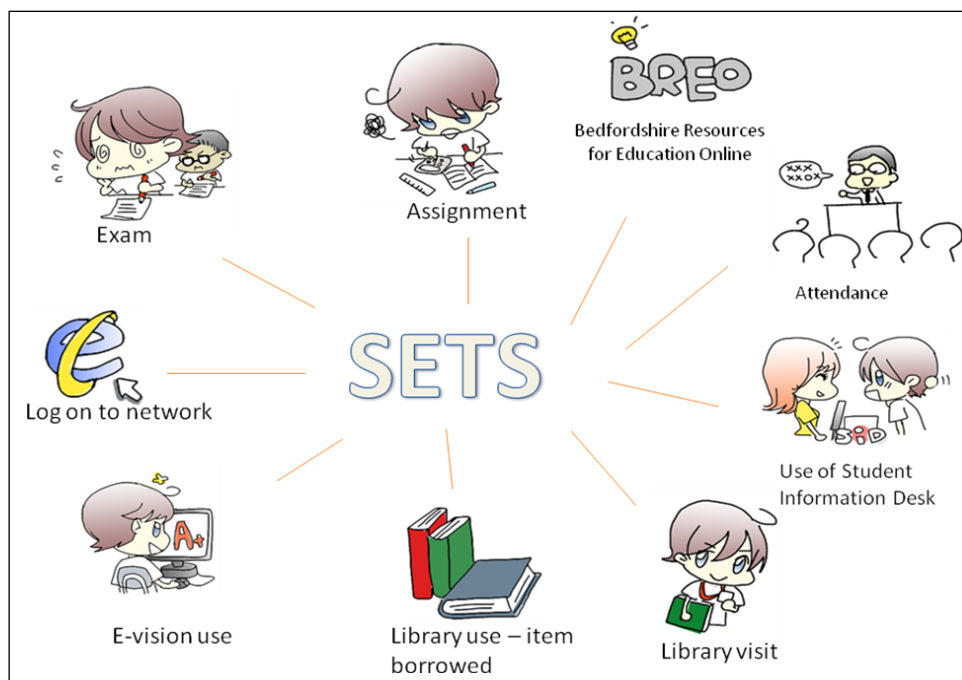
To manage student engagement in their academic study more effectively and efficiently, the University in this context valued the role of ICT and decided to look for better ways of managing student engagement using innovative ICT. As a result, the University and a BI vendor have jointly developed a Student Engagement tracking System (SES). The system aims to enable the users to spot a drop in engagement level before it becomes significant, thus allowing system users’ to identify students at risk of disengagement, so to make early intervention to re-engage students. Data input comes from a number of online and offline sources as shown in Figure 1. Fixed RFID have been positioned in various locations such as, library, lecture theatres and seminar rooms across university campuses. For example, before

entering lectures and seminars, students are required to scan their student card, which identifies the time and the place or event attended. Events also include: library attendance, exam attendance and assignment submissions. Student online login information, such as BREO (Blackboard virtual learning environment and support system), University email and digital library are also collected by the tracking system. This information is then communicated back to a central database within the University. SES also interacts with other information systems including student database which consists of personal and academic information held by the University for each student.

Although the system went live in December 2009, it served as merely an information source, rather than a decision support environment at the time. Furthermore, users of the system highlighted that the current systems' interface was fairly basic and expressed a desire for enhanced functionalities. The University felt that the system had great potential and would like to build on the system further. Consequently, the University has expressed an interest in developing a BI solution in order to improve the functionality of the existing SES, so the University is able to monitor and understand student engagement behaviours at different levels (individual, group and cohort, etc).

Fig. 1

Data sources of student engagement tracking system



The concept of BI is steadily rising up the priority list within various Higher Education Institutes (HEIs) (JISC, 2011a). Some universities use BI to analyse class failure patterns to identify at-risk students and direct them to appropriate support services (Durso, 2009). Dekker *et al.* (2009) and Kotsiantis *et al.* (2003) use data mining tools to predict student's dropout. However, Chaudhuri *et al.* (2011) state that today it is difficult to find a successful enterprise that has not leveraged BI for its business. Yet, despite the potential and promise of BI solutions, most of them fail to provide timely, meaningful and relevant insights for decision makers. Wixom *et al.* (2011) argues that to create an enterprise-wide BI capability is a journey that takes time. Therefore, the project reported in this paper aims to apply BI in a UK university and develops better understanding on the critical issues surrounding the BI success from socio-technical perspective. Organisational, human and technical factors are examined and discussed in the context of BI applications in the Higher Education sector.

This project is funded by the UK Joint Information Systems Committee (JISC)'s BI programme. JISC is a United Kingdom non-departmental public body whose role is to support higher education and research, by providing leadership in the use of ICT in learning, teaching, research and administration. Following UK JISC strategy 2010-12 to help institutions develop and use their corporate and business systems efficiently and effectively, JISC launched the Business Intelligence Programme (JISC 2010) in line with its aim to work with managers of higher education in the areas of BI and BI systems. This project attempted to apply BI in managing student engagement in the UK HEIs. More specifically, it explored how BI can utilise the multi-dimensional data set collected from the University's existing SES to enhance decision making and planning for managing student engagement.

4. Action research

The methodology of this research can be described as an Action Research (AR), which is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including **problem diagnosis**, **action intervention**, and **reflective learning** (Avison, Lau, Myers, and Nielsen, 1999). More specifically, it is a research focusing on change and reflection, involving researchers and practitioners actively participating in an organisation change situation whilst conducting research aiming to make contributions to theory and knowledge. There have been frequent calls for IS researchers to make their research more relevant to practice two decades ago, yet it seems IS researchers continue to struggle to make excellent research practically relevant (Baskerville and Meyers 2004).

Action research aims to solve current practical problems while expanding scientific knowledge. Unlike other research methods, where the researcher seeks to study organizational phenomena but not to change them, the action researcher is concerned to create organizational change and simultaneously to study the process (Baburoglu and Ravn 1992).

In this project, our action research aims to influence BI design and deployment and maximize its impact. All authors are key actors as they are the project team members.

4.1 AR stage one - Problem Diagnosis

The main objectives at the start of this project included identifying the BI toolkit requirements specification. From the socio-technical perspective, the human actor is integral part of BI system and their views and expectations should be thoroughly sought and considered. This involved an examination of the current and expected level of BI in the areas of student data and information from stakeholders' point of view. User requirements were identified using a number of methods including the survey, focus group and interview with existing and potential BI users.

A university wide BI survey was carried out with academic, administrative and management staff. The questionnaires were distributed through a number of channels. For example, they were distributed to administrative staff through faculty managers, to academic staff during the university's teaching and learning conference, and the business school's faculty conference. Forty two validated questionnaires were received. Survey respondents covered key representatives of staff, including all levels of academic staff, field administrators, faculty managers, course leaders, researchers and senior managers. Respondents also provided their comments and suggestions via open questions in the survey.

One focus group discussion was carried out with academic staff in the department of Business Systems in the Business School. The focus discussion collected views and opinions on how to make better use of SES and the potential applications of BI with SES data and the anticipated challenges. One "think tank" meeting was hold with senior management staff and key SES users to discuss the future of SES and its improvement. A brain storming session was carried out with the think tank meeting participants to collect views and ideas related to the benefits, limitations and problems of the current SES.

Six interviews were undertaken. Three interviews were conducted with academic staff to understand their needs and requirement for the better use of SES data. Three faculty

managers who have used SES in supporting their work were also interviewed to discuss their experience and opinions on the use of SES and the potential applications of BI systems.

Across all the investigations by using surveys with 50 users, 2 focus groups and 6 interviews, there was a general consensus that the current SES is potentially very valuable in supporting institutional decision making on student engagement. The SES project has had profound impact on student behaviour especially in attending classroom based learning activities, such as lecture, seminar, and workshop. However, most users agreed that the SES requires further enhancement and development to be considered as usable. Summary of benefits, problems and limitations of current SES are outlined in Table 1 below.

Table 1
Benefits, Problems and Limitations of SES before BI Project

Benefits	Problems and Limitations
<ul style="list-style-type: none"> ▪ Positive impact on student behaviour ▪ More effective and efficient student management ▪ Evidence based feedback to students ▪ Early Interventions ▪ Real time monitoring ▪ Meet UKBA & other legal requirements ▪ Inclusive, reliable data that can be used for comparisons across different student groups 	<ul style="list-style-type: none"> ▪ System speed - The sheer amount of data collected makes the initial system unable to provide acceptable speed for user to use the system. This was identified as the bottleneck for making further use of the current SES. ▪ User interface – the user interface was not user friendly and flexible. ▪ Data output – this was regarded as not operational useful and action-oriented at the moment. ▪ Data sources and modes of engagement – nine engagement areas were used to collect student engagement data, but it may not provide a complete and true picture of the student engagement. Therefore, other important sources should also be included. ▪ Lack of the integration with other student data systems. ▪ Lack of ability for user customisation – users were not able to play with the data to suit their own priorities and needs.

Another part of action research in this stage was to identify the SES current situation and its future state that the university wished to reach. This involved two forms of assessment:

conducting a questionnaire survey designed by the project team and evaluating the ICT maturity level using the Maturity model of Self-Analysis provided by JISC's Strategic ICT Toolkit (<http://www.nottingham.ac.uk/gradschool/sict/>).

The questionnaire survey was distributed to nine members of the Business Action Group (BAG) team who were responsible for determining exactly how the SES should be improved to best support student experience. The members were the key SES stakeholders from Learning Resources, Information Systems Department, Student Services, Faculty Admin, International Office, and academics.

Six responses were received and the consensus was that the present state of SES was by and large in stark contrast to the future state of SES with regard to sources of motivation, decision-making and governance, sources of knowledge and guarantee and sources of legitimacy. In general, the current state of SES was much narrower than the future state of SES. For example, regarding the sources of motivation, which concerns where a sense of purposefulness and value come from, the current state of SES considered fewer client, limited purpose, limited scope of systems integration, and limited scope of measure of systems success than the future state. Regarding decision-making and governance, that is, who is in control of what is going on and is needed for success, the current state, comparing with the future state, had limited control of resources, an incomplete understanding of the decision environment, and no involvement of the senior decision-makers.

4.2 AR stage two – Action Intervention

Having identified the gaps between present and future SES status and problems with SES and established the user requirements for an improved SES with BI solutions, the project team worked closely with internal and external key stakeholders to develop interventions. Equipped with a socio-technical understanding of IS applications, the project was not just looking for technological interventions, but those underpinned by the concept of technology-organisation-people working as whole in achieving the project objectives.

Based on the evidence of our various empirical research methods, users and potential users of SES have highlighted three essential requirements for improving current SES with BI solutions. Working in partnership with the IT supplier and other key stakeholders, such as registrar, internal ICT, BI researchers, and academics, the project team has attempted to address the requirements as explained below:

Student engagement measurement index - Most users would like to have the flexibility for selecting engagement measurement criteria. The student engagement measurement index provides the ability for users to customise engagement measurement index (engagement KPI). Three important functions are then provided by SES for users to:

- Use default engagement measuring index – The index is developed based on the common perception and definition which constitutes student engagement.
- Customise the index system with their selected engagement types. Users are now able to pick and mix different engagement data types captured by the system.
- Prioritise the importance of different types of engagement, e.g. class attendance is more important than others. The system is now able to let users to define their own weighting parameters to reflect their priorities. Another desirable function can be added in the future to provide a tool to assist their decision making. For example, Analytic Hierarchy Process (AHP) can be incorporated.

Interactive and personalised dashboard for engagement reporting - Users are expecting an interactive dashboard for retrieving outputs from the system. The interactive dashboard provides the ability to create recurring standard report and ad hoc (demand) reports through an interactive dashboard. Users are now allowed to modify and save their report parameters, such as frequency, date ranges, course and/or unit cohort.

Automatic risk alert system - Users find it useful to have some kind of alert functions in SES for monitoring disengaged students who are at risk. The risk alert function provides the ability to alert users of exception activity of student engagement, for example, disengaged students who are at risk can be identified early in a course. Users can be notified automatically through push mechanism, such as email, pop-up window. The improved SES has functionalities of alert function available in the following areas:

- User can define the thresholds of risk alter for individuals or groups.
- Ability to flag out individual students or groups at risk automatically.
- Exception data can be flagged out through the pop-up window of the system.
- User can specify the email address and select different frequencies (weekly, monthly etc.) to run the push report.

4.3 AR stage three – Reflective Learning

AR is an iterative process, so the reflective learning should start from beginning of the project and improves along the process. Socio-technical approach of IS research is used as the main

theoretical lens for reflective learning. Therefore, critical issues of technology-organisation-people surrounding the successful BI development and deployment were examined. For example, a number of key questions were raised and reviewed:

- *Technology* – What emerging ICT are used or to be used? What are the technological challenges in managing the “big data”? In this case, technologies include IT hardware, e.g. RFID devices, Oracle database, etc.. and software, such as data warehousing, Oracle BI platform, bespoke BI tools, etc.
- *Organisation* – What are the strategies and processes involved in the university-wide student engagement management practice? How is SES perceived to be part of the student engagement management process to improve its efficiency and effectiveness? The primary objective of SES is to facilitate and support intelligent student engagement management process which is complex and dynamic in nature. Student tracking data are from almost all areas of student learning activities. The value of the system outputs for the institution is enormous, but the realization of the system value is the significant challenge.
- *People* – who are the key human actors involved? What are their roles and what are the ways that they interplay? What is the impact of human behavioral issues? A diverse range of actors have been identified in BI development and deployment. Most importantly, as the student engagement management is organization-wide operation, particular attention will be paid to the managerial challenges and human behavior towards BI success from socio-technical perspective in our reflective learning.

4.3.1 Initial Assessment of the Improved SES

The initial assessment of the project shows that the project has transformed the University’s BI maturity to a higher level, whereby an improved student engagement system with BI solutions have been developed and implemented. Relevant student engagement data sources are now automatically and efficiently collected and processed for reporting through a number of interactive dashboards. These dashboards present various types of visualisation to users and allow users to make better informed decisions related to student engagement management and retention. The improved system also gives users the flexibility to customise the system and reporting based on their respective requirements.

4.3.2. Analysis of tangible and intangible benefits

So far, SES has achieved the following tangible benefits:

- The number of active users has increased which leads to senior management buy-in for more user licenses and for installing more engagement monitoring equipments across the University. For example, the number of SES direct users has increased from 6 users at the start of the project to 100 active users at the peak time of SES usage.
- The diversity of the types of the users is now increased, so is the number of applications. Whilst the main users are admin and sample academics, there is an increasing indirect use by personal tutors. The university has recruited eight additional administrative staff to utilise the information provided by SES. These members of staff are faculty student attendance trackers and engagement offices who are relying on SES to support their work. They use SES to provide information service to managers and tutors, thus enhance the benefit and impact of SES.
- The SES mechanism to capture individual student's movement on the campus has been developed and the data is now stored in a central database.
- Student engagement behaviour overall has improved over the period. For example, positive changes include an increased level of class attendance and student use of the library. Library utilisation rate at the peak time (e.g. 11am in the morning) increased from 80% to 95% in the main campus library.
- Student engagement team can have a holistic view of student engagement Patten and identify students at risks. Timely actions can be made with Personal Tutors, which was not previously possible.

Intangible benefits so far include:

- Improved knowledge and understanding on Big Data and BI among stakeholders and raised awareness on the strategic value of the Big Data and BI in the university
- Shared ICT services are much improved; ICT, Learning Resources, and academics are now working in partnership.
- Demonstrated the case for making informed and evidence based decisions on student engagement activities
- Improved acceptance by managers and tutors on better risk management by identifying students at risk at earliest stage, thus taking timely and more proactive approaches for improving student retention.

4.3.3 Socio-technical perspective reflections

Early reflection learning from socio-technical perspective provides useful insights into issues related to institution wide realisation of the Big Data and BI potentials and impact:

Technology –Technology was and still is the bottleneck of our Big Data utilization project. Numerous problems with data collection devices and database system bugs prevented the expected level of BI applications. One notable technical challenge is managing and monitoring the engagement data collecting devices to ensure the data reliability and accuracy. Another is how to manage the daily growth of overwhelming volume of data which affect the system speed. This is still an ongoing challenge as our Big Data is still growing rapidly daily. The university is seeking to migrate the data warehouse to a more advanced Big Data platform at the moment.

Organisation – From the fusion and transformation point of view, it is necessary to raise awareness among senior managers on the importance of seeing BI as an embedded component of student engagement management system, thus needs systematic interventions from top management team. Organisation implementation strategy, guidance, and system ownership are also important issues to address. A clear system governance structure should have been considered at the very early stage.

People – Most of challenges and inhibitors appear to be centered around human issues. Misunderstanding and mismatch of expectations among IT providers, managers, academic staff and faculty administrators can cause delays and affect the success significantly. The project raised awareness of key stakeholder involvement. For example, the students as the passive participant of SES was not initially consulted. The project team raised awareness on the importance of students' involvement and conducted a focus group with 20 students. Their feedback was very positive in relation to the university's use of SES for improving their experience although they would like the university to explore the possibility of letting students to access their engagement level and benchmark their individual engagement level with their peer group directly. The key findings from the focus group were provided to the relevant university managers.

Since the project collects data related to student activities and their physical whereabouts, it would have certain ethical implications regarding the use of data. The UK Data Protection Act has been strictly followed by the university and student consensus is obtained regarding collecting and using their engagement data. Our students' focus group discussion revealed that students generally trusted the university's systems and were very relaxed about the use of

their data. They didn't show particular concerns regarding ethics. However, big data project does pose challenges for ethical issues that can not be overlooked.

4. Conclusion

This action research concerned with utilising the value of Big Data through the organisation wide development and deployment of a BI enhanced student engagement management system in a UK university. Informed with socio-technical arguments and employing action research methodology, this paper reports and reflects our experience in making Big Data and BI work for UK Higher Education Institutions (HEIs), and attempts to understand the critical issues related to the Big Data and BI implementation. Research so far has involved undertaking surveys, interviews and focus groups with key stakeholders to benchmark past, present and future BI maturity level, establishing the problems and use expectations, identifying impacts and strategic directions. The research has had impact on student behavior, student management, and evidenced-based decision making. but the project has faced a number of challenges in making the Big Data and BI work.

This action research is still an ongoing process. SES is not an end product for the university, but a vehicle which will transform the university to a higher level and more integrated student management system using Big Data and BI. The university will

1. Explore further opportunities to develop more advanced BI toolkits for student engagement analytics and more strategic view of BI dashboard visualisation for senior management team.
2. Incorporate learning analytics and predictive tools, for example to benchmark and predict student performance against their engagement patterns, to analyse and predict patterns of engagement of different groups (e.g. culture, ethnicity, age, etc.)
3. Investigate the market place to identify the appropriate BI tool to support future "Big Data" projects. Following standardisation on a new University standard the current SES system software will, at a minimum, need to be ported to the new code. Although it is too early to make a firm decision it is likely that the system is to be subsumed into a larger scale in-house development.
4. Use of the "Big Data" concept to develop a data warehouse and analysis system to link the current mifare and UHF based attendance tracking hardware with timetable data to provide smart tracking information to student trackers and personal tutors.

This would make a significant impact on the University's strategic objectives related to retention and attainment.

Looking for the future, there are many new opportunities for researchers working on Big Data. One important opportunity is to use the Big Data for educational innovation and to discover “**the ‘next big things’ for education**”

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