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Educational Big Data and Its Functions

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Abstract. An understanding towards the economic value of data led the organizations to collect more data and this paved the way for the term "big data" to arise. Today especially the companies that operate in e-trading add to the importance of "big data" by transforming data into financial gain. The inner characteristic of data as a source which does not run our when spent places it in a special location among all organizational assets. Along with the pandemic, educational activities were transferred to the digital platforms and this increased the importance of big data in education systems. The digital platforms contributed to the collection of more data about students' academic performance, their learning styles, preferences and tendencies. This kind of data can be utilized for different purposes such as improving digital learning platforms, individualization of learning processes, developing teaching processes based on data and providing real time flowing data about academic performances of students. Learning is an individual process and data about individual needs, preferences, styles and tendencies can help develop individualized learning and teaching ecosystems at schools and school areas. This study aims at developing a framework for the functions of big data in the field of education.

Keywords. Big data ecosystems, educational data mining, learning analytics

Introduction

Big data refers to the type of data which cannot be analysed through classical analysis methods and tools owing to its volume (Cielen et al., 2016, p. 1). Big data is the one which is produced in colossal volumes in disciplines where algorithmic and technological tools mediate data collection processes (Richterich, 2018, p. 4). The volume is not the only characteristic of big data. Big data has some other features such as velocity, variety and its features make it impossible to analyse and store it with classical analysis methods and storage tools (Narayanan, 2014, p. 2). This has brought about the developments in the data analysis instruments. The reason is that big data is collected from a variety of ecosystems

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where data is produced by different components of education business. There are some components which constitute the big data ecosystems;

- *The ones producing the big data:* These are the instruments, organizations and systems which produce data. They increase their data storage capacity as more data is produced (Rad & Ataei, 2017, p. 38).
- *The ones collecting data:* These are the tools mediating the business of data collections such as mobile phones, tablets and computers (Rad & Ataei, 2017, p. 39).
- *The one aggregating data:* These are the ones who find out the patterns in data collected from different sources. They give meaning to separate data forms and make it a final product for people and organizations (Rad & Ataei, 2017, p. 39).
- *The ones consuming data:* These are the ones who benefit from data and use it for gaining a personal or organizational profit (Rad & Ataei, 2017, p. 39).

The awareness towards the financial value of big data in commercial institutions has attracted the field of education too and it has been recognized that big data can have some functions in educational systems and can provide solutions to some rooted problems (Rao & Baglodi, 2018, p. 1). The functionality of big data in educational disciplines caused the birth of a term called "educational big data". Demographic data, students' academic achievement data, instructional data (Datnow & Park, 2014, p. 21), data about teaching and learning processes and teacher quality (Rasheed, 2018, p. 5) are some of the sources of "educational big data". The digital transformation in education and educational administration accelerates the collection of educational data, contributing to the volume and velocity of big data in education. When analysed efficiently and turned into actionable information, educational big data can perform crucial functions. In the following section, the functions of educational big data are discussed briefly.

1. The Functions of Educational Big Data

The field of education becomes more data-rich every day. In the last decades, as the demand and need for distance education increased owing to some factors as pandemic and developments in virtual learning environments, interaction among teachers and learners lessened, however, more data about the interaction has been collected through the digital learning applications and online platforms. As more data collected, educators and educational administrators started to make use of it to improve teaching and learning processes. Today educational big data serves for several important functions in the field of education. Some of them can be summarized as follows:

1.1. Student Acquisition

Accepting students to educational institutions is different from recruiting soldiers. Today students can get a lot of information about the institutions which they plan to enrol beforehand through web sites, social media and so on. They also have the chance to contact the already enrolled students of the institutions through forum sites and can get real life experience information about those institutions. Today educational institutions make use of this to attract students by providing information about their educational quality, facilities, social activities, financial support and educational policies (Rao & Baglodi, 2018, p. 1). An effective evaluation towards educational institutions makes it a necessity to have assessment through a multi-perspective view and such a view can be obtained via data from many aspects of the institution. The final product is the educational big data about the institution and it can serve for them to acquire students who are suitable for the needs and requirements of the institution.

1.2. Matching Academia with Business

Successful educational institutions do not confine themselves to acquiring students who have high academic achievement but they also follow their career after graduation. They collect data about their graduate students and they evaluate themselves on how effective they are in terms of preparing the graduates for real life experience. They make us of this data to equip their students with competitive skills which they will need in life after graduation. The educational institutions also collect data about

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their performance and this data can be an indicator for the students about how they will achieve after school. This kind of educational big data can also be a sign for employment and unemployment projections (Bai et al., 2021, p. 10).

1.3. Forming Student Profiles

Educational institutions can make use of data which they have collected to group their students according to some criteria such as learning styles and strategies, social backgrounds and learning handicaps. The data can be made use to cluster students according to their characteristics and better address their needs. This might also help individualize learning processes for each of the students (Li & Zhai, 2018, p. 342). The institutions can serve better only if they have enough data about the characteristics of their students. Therefore, data which will be collected about the students can serve as a springboard for the educational institutions to group students based on objective data-based criteria and provide teaching programs which will address students' needs.

1.4. Management of Students' Behaviours

Management of students' behaviours is an important component for improving the academic performance. Many factors can play a role in management of the students' behaviours, however data about their social habits, their interests, spare time activities are at core of effective management of students' behaviours. Today, student behaviours can be tracked via tools making use of internet of things. Educational institutions can collect data about student behaviours and make use of it to guide management of students' behaviours activities and applications (Velusamy, 2015, p. 15). Moreover, data about students' social backgrounds, families, socio-cultural environments they were grown up can lead the educational institutions to set up effective individual action plans for the management of students' behaviours. Reliable and objective data about students' can be the basis for an efficient behaviour management.

1.5. Improving Teaching Quality

Feedback obtained from the students about their academic performance is one of the key data sources for developing teaching quality. Data gathered about academic achievement levels of students through formative and summative performance scales can guide educators and educational administrators to improve teaching processes. Real time flowing data about students' achievement can inform educators about the factors which affect learning processes. Moreover, consistent predictions about students' achievement levels and pre-requirements for students can guide educators on methods and techniques to increase teaching quality (Yu & Wu, 2015, p. 103). Educational big data can serve aa reference guide in shaping applications targeted at developing and improving teaching quality.

1.6. Establishing a Learner Experience Model

Learner experience is a key element for educational institutions to assess themselves for effectiveness and efficiency. This leads the educational institutions to collect satisfaction data about their teaching programs and activities regularly. Data collected systematically on the satisfaction levels of students can be used to set up a "learner experience model" specific to the educational institutions themselves (Li & Zhai, 2018, p. 342). Big data collected through years about students' satisfaction levels on different aspects of the institution can guide improvements in teaching programs and social activities provided by the educational institutions. This can also be the basis for a sustainable development process flexible enough to meet the changing needs of students and the environments where educational institutions perform.

1.7. Benchmarking

Benchmarking is comparing and contrasting the performance of an institution with the performance of the same or similar institutions or with national standards Kelly (cited in Nazarko et al., 2009, pp. 504-505). In this context, big data about the performance levels of the educational institutions

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can serve as a landmark for educational institutions to evaluate their own performances. This requires to have necessary data about performance levels of the rivals or the partners in the field. Big data for benchmarking can guide the institutions for necessary information to take action to improve their teaching programs and activities. For example, in his study on data-based decision processes, Schildkamp (2019, p. 258) found out that benchmarking data could help schools to determine attainable goals and objectives for themselves. Big data about the performance levels of similar institutions can assist schools and all types of educational institutions to establish goals and objectives which are compatible with the capacity of the institutions. This might also contribute to the competitive capacity of the institutions.

1.8. Evidence Based Learning

Evidence based learning refers to a set of approaches, strategies and processes which make use of data obtained from experimental processes to improve learning (Cranney & McDonald, 2012, p. 1428). The basic requirement of evidence based learning is to enable educators to obtain any kind of data which they will utilize for the purpose of improving learning processes. An institutional big data storage can guide the educators and the whole institution for using data as evidence to increase the quality of learning. Effective student information systems ensure educators to reach data about classroom experience of other educators with a minimum effort. Educators could easily attain data which will add to the learning outcomes and they have the chance to share their own teaching experience (New, 2016, pp. 14-15). These all together form an ecosystem for educational big data which could be the basis for evidence based learning.

1.9. Adaptive Learning

Big data collected by the educational institutions can guide institutions to implement adaptations or changes in teaching processes by taking the individual needs, interests and capabilities into account (Carmel, 2016, p. 3). Liang and Hainan (2019, p. 183) allege that only with big data analysis model it is possible to explore deeply the learners' learning processes, discover the learning styles and preferences, and then provide them with the most appropriate learning content and materials. Especially in virtual learning environments, big data plays a crucial role in restructuring contents and technologies utilized in teaching processes. Digital tools enable educators to collect performance data in the form of a real-time flowing data. They also provide detailed reports about student performance and on the areas where problems arise. In other words, digital tools provide quite a lot of data for formative assessment, which is assessment for restructuring the teaching processes based on the feedback gathered from the field. Big educational data collected in the form of formative assessment could guide the educators to make necessary adaptations in teaching and learning processes, thus contribute to the effectiveness of the processes (Tucker & Stronge, 2005, p. 6). To decide on any kind of adaptation in teaching and learning processes, the healthiest way would be to rely on objective data collected from real educational contexts and environments.

1.10. Appropriate Funding

No educational institution on earth has infinite sources whether human or other kinds of material sources. In this case, effective funding is one of the cornerstones of effective educational management. Objective, dynamic and multidimensional big data can play an important role in allocating financial resources to the most suitable areas in educational institutions (Jiao, 2019, p. 2097). It can also assist institutions to detect the low-income students and direct financial aids to the right students (Zhu, 2020, p. 683). Big data collected from different departments in the educational institutions or in a broader sense, from different institutions in the area could be beneficial in allocating financial and human resources to the most needy areas. In the individual level, detailed data about the students' social, economic and academic backgrounds could constitute the basis for reliable criteria in selecting the most appropriate students for scholarships and financial aids.

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1.11. Developing Individual Learning Programs

Learning is an individual process. To be able to individualize learning processes, educators and educational institutions need data about personal learning needs, interests, learning styles and strategies of each student. Big data in this case forms the basis for preparing teaching programs specific to individual learners. Especially in higher education, which provide a variety of educational programs, contents and materials for learners, it is possible to provide individual learning programs based on big data collected about the characteristics of learners making use of the student profiles created through big data (Kochetkov & Prokhorov, 2017, p. 3). Big data can also assist institutions configure learning processes based on students' former learning experiences. The data about students' career plans, preferences, cultural backgrounds could help design learning contents specific to the needs and interests of the learners (Carmel, 2016, p. 3). Educational big data can also help diagnose students with special learning needs as well as providing them with the suitable learning programs.

1.12. Competency Based Directing

Effective directing is one of the most challenging issues of all educational systems. The main difficulty of effective directing is directing without the necessary data on competencies and skills of the students. Objective data about academic achievement and competencies of students can form the basis for an effective directing. A data based approach in performance evaluation could add to the objectivity of the performance assessment processes (Hitt et al., 2012, p. 408) as well as establishing a solid platform for effective directing. An "educational big data base" established for competencies and academic performances of students might constitute a reliable reference for educational systems in directing students to the appropriate areas of study. This data base could be established in primary school level or even earlier and can follow the students until they finish formal education. These big data platforms could help track academic success as well as their competencies, preferences, learning needs and changing interests.

1.13. Process Management

The evaluation of the teaching and learning processes should be designed in a cyclic structure (Keane & Labhrainn, 2005, p. 4). The reason underlying this is that teaching and learning processes are affected by many factors. Moreover, the content and tools utilized change very quickly due to the technological developments. For instance, digital platforms and applications designed for teaching and learning are able to collect and store real time performance data which could be used as formative assessment (West, 2012, pp. 2-3). The flowing real time data about the academic performance of students could be used to design more effective process management applications in educational institutions. The big flowing data could be a reference to diagnose inefficiencies and enable administrators to respond to them on time. Therefore, educational big data could be a medium for effective process management applications in educational institutions.

1.14. Effective Career Planning

When assessing academic performance of the students, many factors such as their motivation levels, learning styles and preferences, their achievement levels in standard tests, their participation in social activities and their attendance rates could be taken into account. This multifaceted way of performance evaluation requires collecting a great deal of data about a student throughout his or her formal education life. This kind of big data could be utilized as a reference to decide on the possible branches of study which the students could be directed in their future educational career (Alghamdi & Alghamdi, 2019, p. 3815). Digital platforms and tools enabled storing huge amounts of data. This could be used to collect and store individual performance data about students beginning with the earlier stages of formal education. The data collected could follow the students with the different levels of formal education, forming a basis for effective career planning. In such a case, it is crucial that the data base is open to educators, students and their families. The database could help healthy decisions on career planning or at least for accountability in any case of ineffective career plans.

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1.15. Strategical Planning

Educational big data enables educational institutions to reach data in various sources which are in a scattered form. This has some important functions for the institutions: They can respond to changes in educational sector timely and more effectively, they can turn their decisions into an informed form based on data, they can gain a consistent understanding for behaviour patterns of their students, they can have predictions to enhance learning experiences of the students, they can detect at-risk students and take action for the benefit of them and they can design more effective educational policies based on data (Picciano, 2012, p. 11). Educational big data ensures institutions to take objective decisions based on data, to evaluate the needs more precisely and draft their policies in a more flexible manner (Chen et al., 2020, p. 142). When all these are taken into consideration, educational big data can serve as a reference for educational institutions to establish healthy strategical plans, which comprise goals and objectives compatible with the capacity of the institutions and which are attainable in the contexts where the educational institutions perform.

1.16. Monitoring Educational Systems

There are four main components of educational systems: educators, learners, context and content (Berendt et al., 2017, p. 12). To be able to monitor the effectiveness of educational systems, variables belonging to these four components should be tracked. This tracking can only be realized through collecting data about them. Educational systems are in the form of a multi-dimensional structure. Therefore, monitoring educational systems require tracking and collecting data in a multi-perspective manner in terms of social, cultural and economic views (Cantini et al., 2016, p. 219). In such a case, that makes it a necessity for the educational systems to collect and store huge amounts of data about the components which form the systems. This kind of big data store can establish a reliable basis for tracking the effectiveness and efficiency of educational systems and determining the areas which need restructuring.

1.17. Continuous Innovation

It can be put forward that the main motivation behind collecting data in educational institutions and systems is to determine the areas of development and to enable institutions and systems adapt to the changes. When educators, educational administrators and policy makers have the opportunity to reach data about the components of education, they will be able to set up policies and determine practices to improve teaching and learning. Thus data can play an active role in innovation and improvement of educational practices both at the institution and system levels (New, 2016, p. 17). Continuous flowing data could serve as a springboard for a sustainable innovation in educational institutions and systems by data based decision processes on the areas needing development. A continuous development process might need a continuous data collecting about the institutions and systems themselves and determine the areas of development through data based approaches and applications. The institutions and systems need to be fed by regular and systematic feedback from the members so as to ensure sustainability to innovation processes.

1.18. Quality Control Mechanism

Technological development not only led to the improvement of devices to collect and analyse data but also increased the capacity of organizations to store data. This brought about the birth of the term “big data”. As other organizations, educational institutions began to collect and store data without assessing the functionality of it at a specific period, the amount of data increased in a breath taking velocity. The educational big data collected and stored in a longitudinal and comprehensive way might function as a quality control mechanism for educational institutions as they will have data about their actual performance, effectiveness of human resources and allocation of the financial resources to the appropriate areas. The educational institutions could have an understanding for their past experiences so as to form a consistent and reliable vision and mission. Any positive or negative change in

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performance levels could shed light on the quality of the educational programs, activities, contents and materials.

1.19. Improvement of Virtual Learning Processes and Tools

Virtual learning platforms enable collecting and storing real time flowing data about learning processes experienced by students. The great amount of data collected via virtual learning platforms could assist turning online learning processes into a more effective structure. User data on virtual tools can provide data about students' behavioural patterns which have never been found out before. Data gathered could be used to make online contents and materials more attractive and informative for the students (Alonso & Arranz, 2016, pp. 30-31). Virtual platforms provide data on how much time spent by the users for different kinds of contents and materials. When analysed efficiently, this huge amount of data could be used to make necessary adaptations on the contents and the materials to be able to respond to the needs of the learners in more effective way. Big data can also form the basis for individualizing the contents (Ashraf et al., 2015, p. 48). The data about individual learning preferences could be the basis for designing more effective and specific virtual learning contents to address the needs of the students with special learning needs. For example, data about what kind of learning materials (video, audio, text etc.) students are making use of more commonly could be used to design virtual learning ecosystems specific to the individual learners with special learning needs.

1.20. Designing and Developing e-Learning Contents

E-Learning platforms have made tracking students' online learning behaviours an unbelievably easy task for educators. E-Learning contents address students with different learning styles and preferences. For different branches of study, different learning contents might be more functional respective to others. By tracking students online learning behaviours and footprints, it can easily be found out that which e-learning contents best serve for specific learning units and students with different learning styles. Therefore, educational big data could be taken as the basis for designing e-learning contents and materials for different branches of study and for various learning units as well as students with various learning preferences. Educational big data gathered through students' online learning experience could help e-learning content creators in determining what forms of learning materials could be the best options for specific topics.

1.21. Performance Prediction

It is possible to make predictions about the students' future academic performance based on the data about their actual academic achievement levels. The data about actual performance could be taken as the basis for designing educational contents compatible with the capacity of the students. Prediction about the possible future academic performance of the students can also be a reference for the guidance and directing which will be provided for the students. The educational big data about individual performance levels could be beneficial in making predictions about the total performance levels of institutions. Consistent prediction about individual and institutional academic performance might guide educational planning and programming. Regular and systematic data collected about the academic performance could also be a reference for any kind of updates for performance predictions of the students.

1.22. Timely Feedback for Educational Institutions and Systems

Feedback constitutes the cornerstone of formal education and all actions in formal education are realized in the light of the feedback gathered from the systems and institutions (Mayer-Schönberger & Cukier, 2014, p. 11). Especially with the advances in artificial intelligence, feedback in the form of big data is provided for students on their academic performances through online applications and tools with a minimum effort and time (Weber, 2016, p. 66). When institutions and systems collect, store data and turn this data to actionable information, it could serve as an effective source of feedback for institutions and systems. As instruments to collect, store and analyse big data develop by the technological advances,

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it becomes easier for the educational institutions and systems to make use of the real time flowing data about the performances of students, teachers, human resources and all kinds of components of educational institutions and systems.

1.23. Self-Evaluation

Educational big data can be a reference for self-assessment An educational big database which could be formed under each institution or in educational regions could guide the educators and administrators to form an understanding towards their actual performances. Longitudinal big data about actual performances could serve as a reflector on the effectiveness and efficiency of the applications implemented. They will provide an objective basis for adding sustainability to the educational applications or accountability for any kind of changes. They could also serve as balanced scorecards for the institutions and systems and will lead the administrators or policy makers during planned change applications. Educational big data bases or archives could be tools of self-evaluation for educators, educational administrators and policy makers.

1.24. Research in Education

Educational big data gathered in a longitudinal structure could be a source of data for educational researchers. It could help determine the factors which affect teaching and learning processes and form a multi-perspective view for issues in educational institutions and systems. Though educational big data is not the one gathered for research purposes, it can serve as a reference to gain new insights to the current complex problems of education systems. Moreover, as the research will be carried on already collected and stored data, educational research based on it could diminish the expense, effort and time spent on research process. Though being a secondary data, educational big data collected and stored over time could shed light on the current issues of educational institutions and systems. They can also be used to enlighten the factor affecting the quality of teaching and learning processes, which constitutes an integral part of educational researches.

1.25. Contributions to Learning Analytics

Learning analytics is a discipline in which data about the context where educators and learners perform their responsibilities is collected, analysed and reported for the purpose of forming a healthier understanding towards learning processes and activating the environment where learning takes place (Siemens, 2013, p. 1382). Learning analytics has three different levels: Macro, meso and micro. Macro level refers to the national dimension, meso is at the institutional level and micro refers to the learning analytics carried out at the individual level (Shum, 2012, p. 3). Educational big data can serve all these three levels of learning analytics by providing data about the environmental and contextual factors affecting learning and teaching processes. Educational big data can provide valuable data to gain deep insights to the teaching and learning processes on individual, institutional and national levels. Educational big data gathered could guide any kind of actions taken to improve teaching and learning processes in all three levels of learning analytics.

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