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Development of Smart Curriculum in Terms of Operational Research Methods

Volkan DURAN[1], Murat GÖKALP[2]

Abstract

This paper aims to propose the implementation of a smart curriculum via different algorithms based on operational research methods. The study is a theoretical and qualitative study made with the document analysis method. A theoretical structure has been tried to be created by obtaining the data from studies related to the concept of smart education. A smart curriculum can be defined as a new type of curriculum having the features of adaptation, sensing (awareness), inferring (logical reasoning), self-learning, anticipation, and self-organizations and restructuring feedback to adapt itself the various differentiated instructional methods. When dealing with complicated implementation issues, operational research (OR) is the field that makes use of models, either quantitative or qualitative, to assist in decision-making. For more than 50 years, emergency medicine and the interface between acute and community care, hospital performance, scheduling and management of patient home visits, scheduling patient appointments, and a variety of other complex implementation problems with an operational or logistical nature have been addressed using OR methods in different fields. In this respect, we theoretically show how to implement those methods based on algorithms in the smart curriculum development process via different algorithms and the methods regarding intelligence theories. More detailed algorithms can be proposed in curriculum evaluation and development models.

Key Words: Smart curriculum, operational research, qualitative research

Yöneylem Araştırması Yöntemleri Açısından Akıllı Bir Eğitim Programı Geliştirme

Özet

Bu makale, yöneylem araştırması yöntemlerine dayalı farklı algoritmalar aracılığıyla akıllı bir eğitim programı uygulanmasını önermeyi amaçlamaktadır. Çalışma, doküman incelemesi yöntemiyle yapılmış teorik ve nitel bir çalışmadır. Akıllı eğitim kavramı ile ilgili çalışmalardan veriler elde edilerek teorik bir yapı oluşturulmaya çalışılmıştır. Akıllı bir eğitim programı, adaptasyon, algılama (farkındalık), çıkarım yapma (mantıksal akıl yürütme), kendi kendine öğrenme, tahmin etme ve kendi kendine organizasyon ve çeşitli farklılaştırılmış öğretim yöntemlerine uyum sağlamak için geri bildirim ile kendini yeniden yapılandırma özelliklerine sahip yeni bir programt türü olarak tanımlanabilir. Karmaşık uygulama sorunlarıyla uğraşırken, yöneylem araştırma (OR), karar vermeye yardımcı olmak için nicel veya nitel modellerden yararlanan alan olarak bu bağlamda yardımcı olabilir. Yöneylem araştırmalar 50 yılı aşkın bir süredir, acil tıp ve akut ve toplum bakımı arasındaki arayüz, hastane performansı, hasta ev ziyaretlerinin planlanması ve yönetimi, hasta randevularının planlanması ve operasyonel veya lojistik bir yapıya sahip çeşitli diğer karmaşık uygulama sorunları, kullanılarak ele alınmıştır. Bu doğrultuda, bu çalışmada akıllı eğitim programı geliştirme sürecinde algoritmalara dayalı bu yöntemlerin farklı algoritmalar ve yöntemler aracılığıyla nasıl uygulanacağını teorik olarak göstermek amaçlanmıştır. von Neumann makineleri " olarak adlandırılan kendi kendini kopyalayan makinenin temel algoritmik yapısı bu bağlamda bireysel bir eğitim programının kendi kendini bireye özgü hale getirmede kullanılabileceği mevcut akıllı eğitim program özellikleri göz önüne alınarak yeniden düzenlenerek bir model olarak ortaya konulmuştur.

[1]Sorumlu Yazar, Dr. Öğr. Üyesi Volkan DURAN, Iğdır Üniversitesi, volkan.duran8@gmail.com, https://orcid.org/0000-0003-0692-0265
[2] Prof. Dr. Murat GÖKALP, Ağrı İbrahim Çeçen Üniversitesi, muratgokalpm@gmail.com

Akıllı eğitim program değerlendirme ve geliştirme modellerinde daha detaylı algoritmalar bu noktada önerilebilir. Ayrıca, akıllı bir eğitim programının fiziksel altyapısı üzerine daha derinlemesine analizler ve deneysel çalışmalar yapılabilir.

Anahtar Kelimeler: Akıllı eğitim programı, yöneylem araştırmaları, nitel çalışma

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Introduction

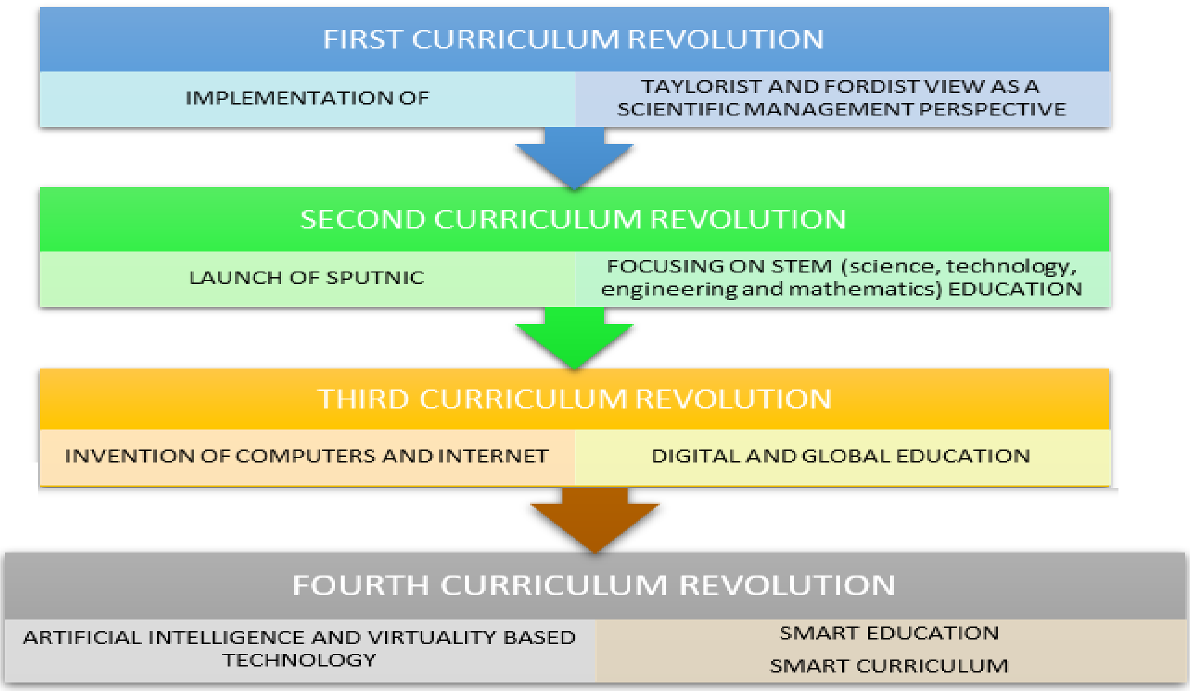
One of the characteristics that separate the twentieth century from the preceding centuries from the viewpoint of education may be viewed as the development of curriculum and instruction theory throughout that period. Even while certain methods and techniques, as well as some processes, were used in education before the nineteenth century, they were not considered curricular models in the modern sense of the word until the twentieth century (Carl, 2009). As a consequence of the increased need for trained employees throughout the nineteenth century and following the establishment of the industrial revolution, educational institutions were forced to reorganize to meet the needs of the modern world (Smith, 2012). While both the Taylorism understanding, which seeks to systematically analyze the production process and determine every task be completed to the finest detail and the Fordist understanding, which emphasizes more specialization, were effective in the field of pedagogy, the Fordist understanding was the most effective. As a result, curriculum and teaching were recognized as the distinct field around the turn of the twentieth century. In addition, it is anticipated that education will become more planned and scheduled in a variety of ways as a result of this. In 1918, Franklin Bobbit wrote the book entitled " The Curriculum" (Demirel, 2015) as a systemic approach reflecting those understandings in terms of scientific management. Throughout the United States of America, Bobbitt's research on curricula is especially important as he extends Frederick Taylor's principles for science management to school administration and preparation. Bobbit claimed that schools such as companies would be efficient, by disposing of waste and using the training to render students, adult employees. Bobbit, along with Friedrich Winslow Taylor, thought it was appropriate to focus on the correct and top-down (central authority) method to produce outcomes for all activities carried out in educational processes (Ireh, 2016; Duran, 2017, p. 255).

The second major event in curriculum history was the launch of the Sputnik satellite by the Union of Soviet Socialist Republics (USSR). Americans were stunned when the USSR conducted the first human space trip in 1957! The reaction was swift and strong. As a result of these developments, the government has increased funding for scientific research and education throughout the previous few decades. Despite their global impact, these changes were most visible in public schools. (Garrett, 2008; Herold 1974, p.144). For this reason, the Launch of sputnik resulted in many changes in the USA, such as the Apollo program for landing the moon, as well as curriculum revisions which more focus on STEM (Science, Technology, Engineering, and Mathematics) programs. It can be said that the primary catalyst for the curriculum "revolution" in the USA was Sputnik. Before Sputnik, curriculum reform was the concern of a few people and a few experts (Herold, 1974, p.157; Akpan, 2017, p.183-188).

The third revolution for the curriculum theory could be regarded as the invention of computers and the internet (Oblinger & Oblinger, 2005). The revolution in the world of information started in 1946 with the first computer. Inventions of computers brought up many new approaches qualifications for the development of curriculums and modeling instructions (Huntington & Worrell, 2013). First of all, computer technology makes information more realistic by bringing visual, sound effects through multimedia presentations in terms of education. Secondly, it brings new knowledge domains such as algorithms, coding, and basic computing skills in education (Kulik et al., 1985) located themselves in the new curriculums. Curriculums had even tutor roles by providing instruction, feedback, and testing as well as had a tool role. Through computers, students have the opportunity to repeat any topic and organize them irrespective of time and space. Computer-based feedbacks will also provide students with the opportunity to make perfect practice at any time and space. Improving computer technology offers new teaching materials such as simulation and animation in education also. Today, computers (1) are used as a subject in teaching (2) education management and (3) as a tool supporting education (Erişen & Çeliköz, 2009: 124). Therefore, curriculums were changed according to the demands of computer technology in this respect. Currently, all fields of computer science and modeling are widely used as a tool of real learning, design automation, and training (Dementiev et al., 2015; Kara and Demir, 2009; Gürüz, 1994, p.33).

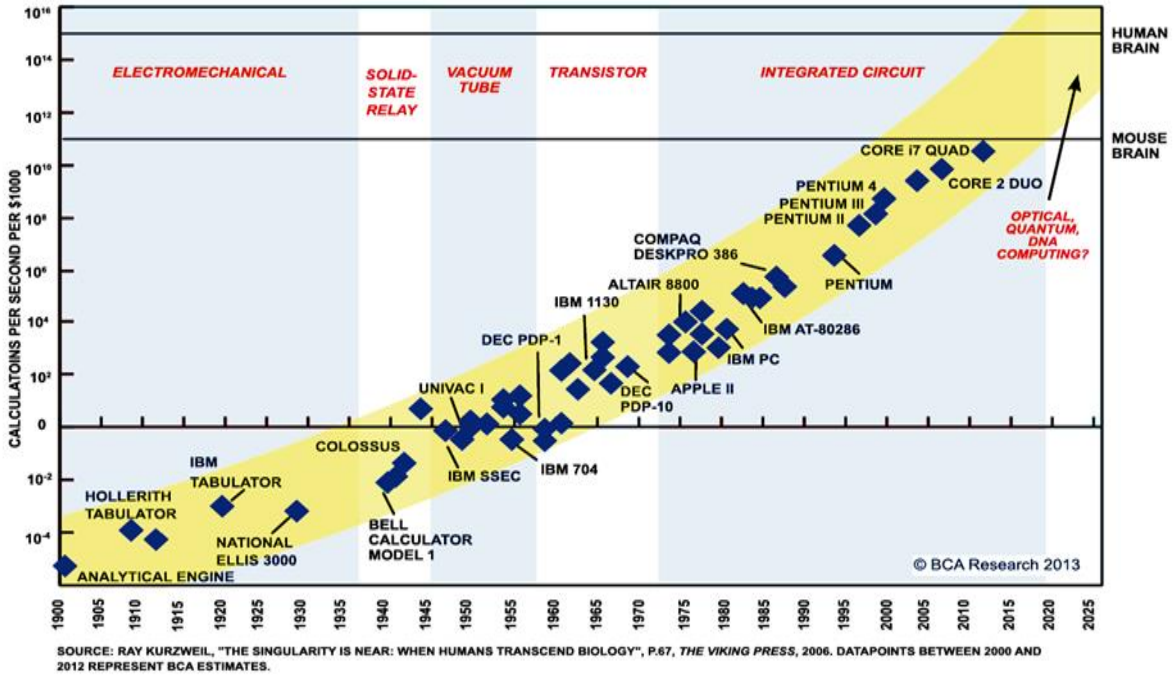
To sum up, as schematized by Figure 1, there are three curricular revolutions and the fourth one may imminently occur in the near future. The first one is the adoption of Taylorism and Fordism as a scientific management viewpoint in every planning process of social life. Second one is the launch of Sputnik that ignited and stretched the Cold War into the zone of science, media, literature. The third one was the implementation of computers and internet so that knowledge was more accessible and mass culture and education was more widely prevalent than previously. Probably, the fourth curriculum revolution maybe connected to the integration of artificial intelligence and virtual educational environments and ecosystem which has arrived to agenda only by the introduction of the notion of metaverse (Maharg & Owen, 2007).

Figure 1
Four Curriculum Revolutions in This And Last Century



As undesrtood in the Figure 1 the goal of technology is to increase human capability since it extends our biology into the more functional space. For example, watching television boosts our ability to notice things that are outside our regular perception. The steam engine boosts the capacity to regulate resources while also pushing goods beyond the reach of human nature. Furthermore, our technology is progressing in tandem with Moore's law, which states that the number of transistors in a dense integrated circuit (IC) doubles every two years as given in Figure 2. Moore's law will cease to be valid at some point in the future, according to industry experts. Microprocessor architects are claiming that the growth of the semiconductor industry has slowed down below the rate expected by Moore's law since about 2010 (Website 1). Moore's law intuitively shows us that technology will eventually change our lives as well as education irrespective of whether the predictions of Moore’s law hold.

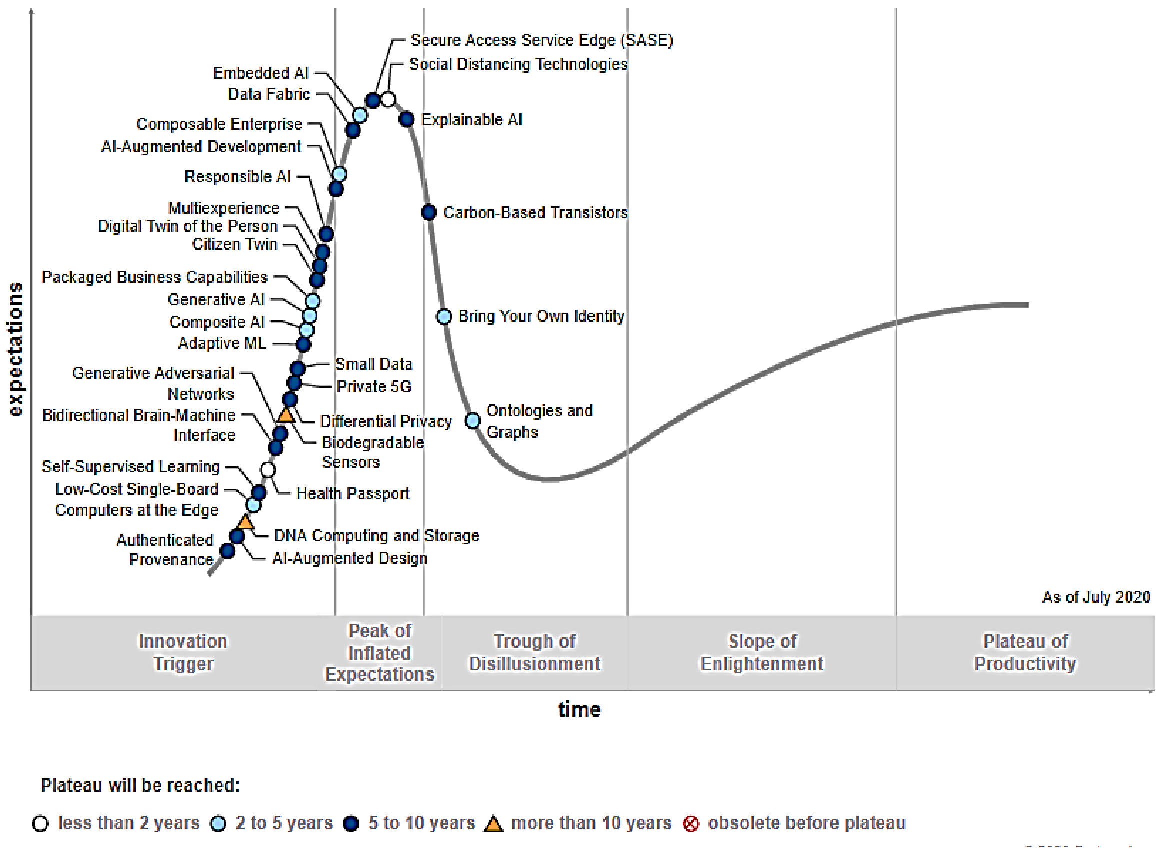
Figure 2
Moore’s Law



Source: adapted from website 2

What is more, Gartner's Hype Cycle for Emerging Technologies 2020 which is depicted in Figure 3 emphasizes technology that will impact industry, culture, and human beings dramatically over the next five to ten years. It requires innovations that allow a composable organization to re-establish the technological trust of society and transform even the brain state (Website 3). In this respect, we can see the key applications of formative AI in the education process and that is what we discuss in the context of smart curriculums in this paper.

Figure 3
Hype Cycle for Emerging Technologies, 2020



Source: adapted from website 4

Figure 3 (Hype Cycle for Emerging Technologies, 2020) implies that as the development of current technologies is considered, the following tendencies are distinguished in the global smart education development practice (Mitrofanova et al., 2019: 575):

- The leading education technology has grown in online or electronic education. Observers conclude the world retains just a few hundred universities by 2050, with millions of subscribers being educated through network technology and telecom facilities;

- Learning personalization is viewed as an alternative to centralized schooling, whereby all students require the same results;

- Personal education systems will be developed to take care of the unique psychological characteristics of particular students and therefore lead to the growth of mental and artistic skills and enjoyment of learning;

- Design and implementation of smart systems in the education process.

Artificial Intelligence can be defined as computer systems to solve highly complex problems such as categorization, forecast, and optimization problems, or to perform natural tasks, which require human ability and can't usually be resolved by classic algorithm-based methods (Haton, 2006; Makridakis, 2017). It is thought that artificial intelligence technology will, therefore, enhance our minds, reasoning, and thinking beyond imagination. In addition to technological developments, as learners become more self-directed and personally engaged in their learning, the educational concepts such as teaching, curriculum, learning also are questioned and will be newly defined in a new and unique way in the future (Mason et al. 2019, p. 207).

Smart education refers to the use of the most up-to-date or intelligent technology in cooperation with sophisticated pedagogical methods, tools, and strategies to provide the most effective delivery of educational services possible (Shoikova, Nikolov & Kovatcheva, 2017). These smart technologies have the potential to completely revolutionize the processes of teaching and learning delivery in organizations (Park, Choi & Lee, 2013). As a result, it may be required to research in order to enhance learning and teaching approaches to engage students who are heavily reliant on digital technology in their daily lives. Examples include cloud-based mobile learning for students, which extends well beyond the scope of remote education possibilities. This means that smart education, in its most basic sense, offers up the potential to improve learning tools and develop instructional delivery methodologies (Singh ve Miah, 2020). As Zhu and Bin (2012) emphasized, to facilitate personalized learning services, intelligent environments must be created through the use of smart technologies.. As a result, the following are some of the possible requirements for a smart learning environment (Hwang, 2014):

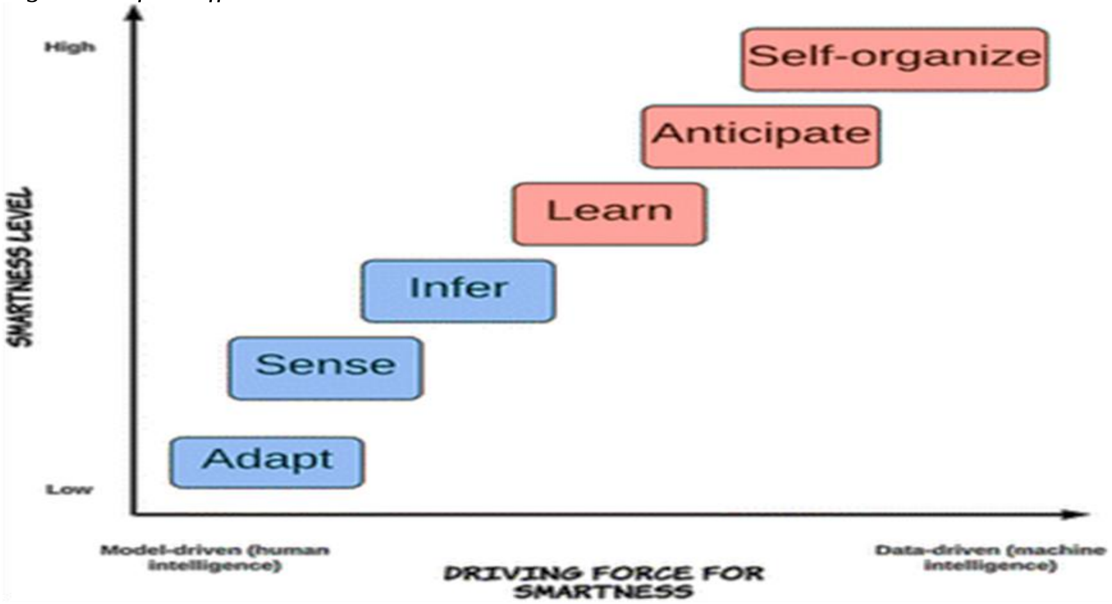
a- A smart learning environment is context-aware, meaning it may provide learning assistance depending on the learner's online and offline state.

b- It may analyze learners' requirements from many viewpoints (e.g., learning performance, learning habits, profiles, and personal characteristics), as well as the online and real-world settings in which they are positioned.

c- In order to fulfill the requirements of individual learners, a smart learning environment may adjust the user interface (i.e., how information is presented) and the topic material (e.g., performance on learning assessments).

Inferring, self-description and self-learning, monitoring of incoming data and anticipation, and self-organization and self-optimization are all part of smart education (Uskov et al., 2019, p. 14). Knowledge collected in the form of metadata ontologies, learner models, learning designs, and other kinds of data gathering and organizing may be used to adapt, perceive, and infer what is happening inside a learning environment. It is increasingly conceivable that systems based on machine intelligence and driven by big data would learn and predict actions without the intervention of a human manager, self-organize, and function as autonomous agents in a learning scenario (Hoel and Mason, 2018). There are many taxonomic stages in the application of smartness in education, as shown by Figure 4. These levels range from adaptability to self-organization. Adaptation might be considered the lowest level of this hierarchy, while self-organization can be considered the greatest level of this hierarchy.

Figure 4
Driving Forces for Different Smartness Levels in SLE.



Source: adapted from " Standards for smart education – towards a development framework." by Hoel and Mason, (2018). Smart Learn. Environ. 5, 3 https://doi.org/10.1186/s40561-018-0052-3

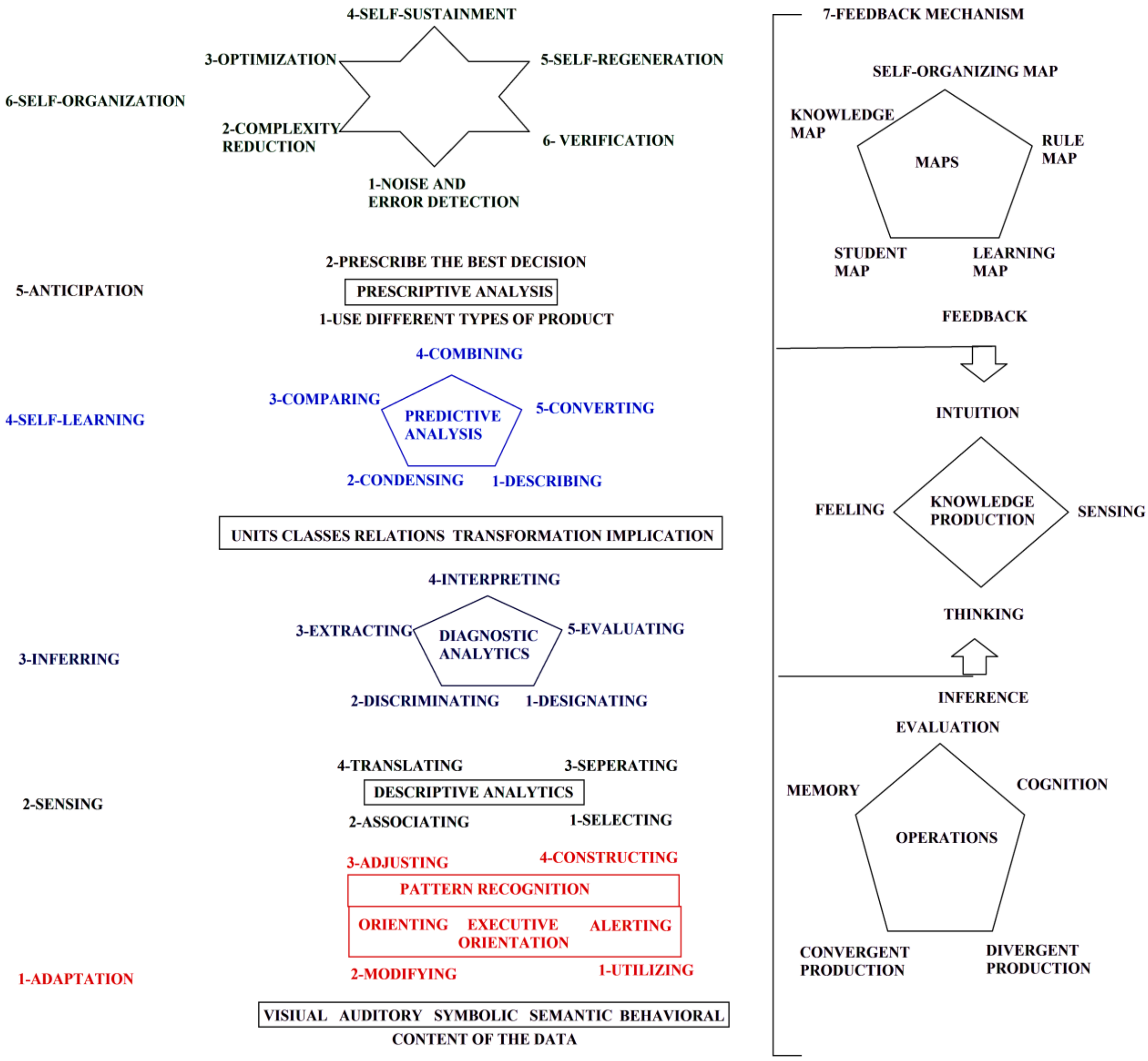
According to Lee et al. (2014), the characteristics of smart learning include formal and informal learning, social and collaborative learning, individualized and contextual learning, as well as an emphasis on application and content development. Accordingly, based on the desire for smart education, ten fundamental characteristics of smart learning environments are given as location-awareness, context-awareness, social awareness, ınteroperability, seamless connection, adaptability, ubiquitous, whole record, natural ınteraction, high engagement (Zhu, Yu & Riezebos, 2016).

In this respect, Hwang (2014) identified context-awareness; adaptiveness, and the ability to adapt user interface, subject content, and report learning status as the key criteria of a smart learning environment. In this respect smart curriculum can be defined as a curriculum having the following features (Shoikova, Nikolov & Kovatcheva, 2017; Uskov et al., 2019, p.14):

1- Adapt: Ability to change one's physical or behavioral features to better suit one's surroundings or to better survive in one's environment.
2- Sense: Ability to identify, recognize, or become aware of the phenomenon, event etc.
3- Infer: Ability to generate logical conclusions from facts, information, evidence, assumptions, rules, and logic.
4- Learn: Ability to learn new or adapt current information, experience, behavior and etc.
5- Anticipate: the ability to think ahead and plan ahead.
6- Self-organize: Internal structure (components) of a system may change purposefully (non-randomly) given acceptable circumstances but without an external agent/entity.
7- Feedback: Sustain self-organization and self-learning with correct feedback.

The general model of a smart curriculum based on these features can be given in figure 5 below.

Figure 5
The General Model of a Smart Curriculum



A multi-layered and sophisticated structure can be seen in Figure 5, which depicts the overall framework of the smart curriculum. For this reason, at the very least, a variety of statistical approaches and technologies are required for theoretic study of the curriculum. Operations research is an interdisciplinary science that draws on a variety of disciplines. The purpose of applying this science to deliver a scientifically optimum solution to a problem is to enhance and optimize the performance of the organization as a result of the efforts made so far (Eroğlu, 2019). Operations Research is a problem-solving approach that involves an interdisciplinary team working together following a scientific technique and considering the complete system. Following is a summary of the issue solution steps that make use of these fundamental characteristics, which are referred to as the Operations Research Approach:

a. Determining the nature of the problem

b. Obtaining and evaluating the essential facts and information about the system

c. Model development and refinement

d. Obtaining a solution from the model and determining whether or not the model is valid. Implementation of the model and decision-making (Sağır, 2012). OR methods have provided macro-level insights on the allocation of resources to the education sector, as well as the distribution of those resources throughout the various levels of education and the various institutions within the sectors, using data from a variety of sources (Johnes, 2014).

Combining OR methods with smart education principles, we encounter the concept of knowledge engineering. The disciplines of knowledge engineering were founded in 1977. It is designed by artificial intelligence principles. When it comes to artificial intelligence, knowledge engineering is the investigation of fundamental questions of knowledge and general solutions. The purpose of artificial intelligence research is to figure out how to make computers smarter, which is one of the most important tasks. It is only through the accumulation of information and expression that computer intelligence can be achieved in the first place (Zhang, Zhao, Ouyang, & Zhao, 2016). Knowledge engineering, when applied to education, results in a kind of knowledge-based system called intelligent tutoring systems (ITS) (Alonso et al. 2003). The task of eliciting knowledge from experts, on the other hand, can be a difficult one because experts are often unaware of the knowledge that they have that they use implicitly when making decisions (Paquette & Baker, 2018). Furthermore, engineers and education specialists are becoming increasingly responsible for selecting technical solutions that are acceptable for their social context and for taking into account the long-term consequences of their work, if only because the work of engineers may have far-reaching consequences., engineers and curriculum developers must draw on a broad range of knowledge, ranging from theoretical tools to contextual knowledge (Zhou, 2012).

To sum up, in the future, education will be eventually based on more technological services ranging from smart technology to the implementation of any virtual or technological devices. In this respect, it is important to examine and make curriculum models based on smart education principles because

- Huge data and information will force people to use smart technologies to deal with this vast data.

- Individuals' needs will become more focused on future education theories because learning how to learn will gain importance rather than learning particular skills or knowledge.

- Future jobs will require more skills that need to deal with smart features of the technologies therefore it will require smartness in education as well.

As a result, the primary goal of this research is to demonstrate how operational research methodologies might be conceptually integrated in smart curricula. Therefore following question was sought in this paper:

1- How Operational Research Analysis Methods can be implemented in Adaptation Phase in the smart curriculum?

2- How Operational Research Analysis Methods can be implemented in Sensing Phase in the smart curriculum?

3- How Operational Research Analysis Methods can be implemented in Inferring Phase in the smart curriculum?

4- How Operational Research Analysis Methods can be implemented in Self-Learning Phase in the smart curriculum?

5- How Operational Research Analysis Methods can be implemented in the Anticipation Phase in the smart curriculum?

6- How Operational Research Analysis Methods can be implemented in the Self-Organization Phase in the smart curriculum?

7- How Operational Research Analysis Methods can be implemented in Feedback Phase in the smart curriculum?

Methodology

The purpose of this study is to conduct a theoretical review using document analysis as a qualitative research approach. A topic, idea, theory, or phenomenon is the subject of a theoretical review, which is intended to concretely evaluate the corpus of an idea that has built on the subject (Campbell, Egan & Lorenc et al., 2014). When it came to the data gathering procedure, the first step was to identify books and articles that were directly relevant to smart curriculum (that is, they had to have the words "smart curriculum" or "smart curriculum" in their title or keywords). Secondly, it was taken into account that these papers should be recent publications that had been published within the previous 15 years. The role of the researcher in this process is to give a voice and meaning around the topic of smart education and then to synthesis the data into a cohesive model, which is known in the field as "smart curriculum," in a logical and objective manner.

The theoretical literature review assists in determining what theories currently exist, how they are related to one another, to what extent the existing ideas have been studied, and to generate new hypotheses that can be tested in the field of psychology (Bowen, 2009). Because of this, the primary goal is to integrate qualitative information to suggest a new model. The information for this study was gathered via document analysis, which included identifying papers that were connected to smart technology and smart education in the context of operational research regarding smart curriculum. Therefore following question will be sought in this paper:

1- How Operational Research Analysis Methods can be implemented in Adaptation Phase in the smart curriculum?

2- How Operational Research Analysis Methods can be implemented in Sensing Phase in the smart curriculum?

3- How Operational Research Analysis Methods can be implemented in Inferring Phase in the smart curriculum?

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5- How Operational Research Analysis Methods can be implemented in the Anticipation Phase in the smart curriculum?

6- How Operational Research Analysis Methods can be implemented in the Self-Organization Phase in the smart curriculum?

7- How Operational Research Analysis Methods can be implemented in Feedback Phase in the smart curriculum?

Findings

In this part, it was examined how some operational research analysis methods can be reconciled and implimented in the stages of smart curriculum given as adaptation, sensing (awareness), inferring (logical reasoning), self-learning, anticipation, and self-organizations and restructuring feedback.

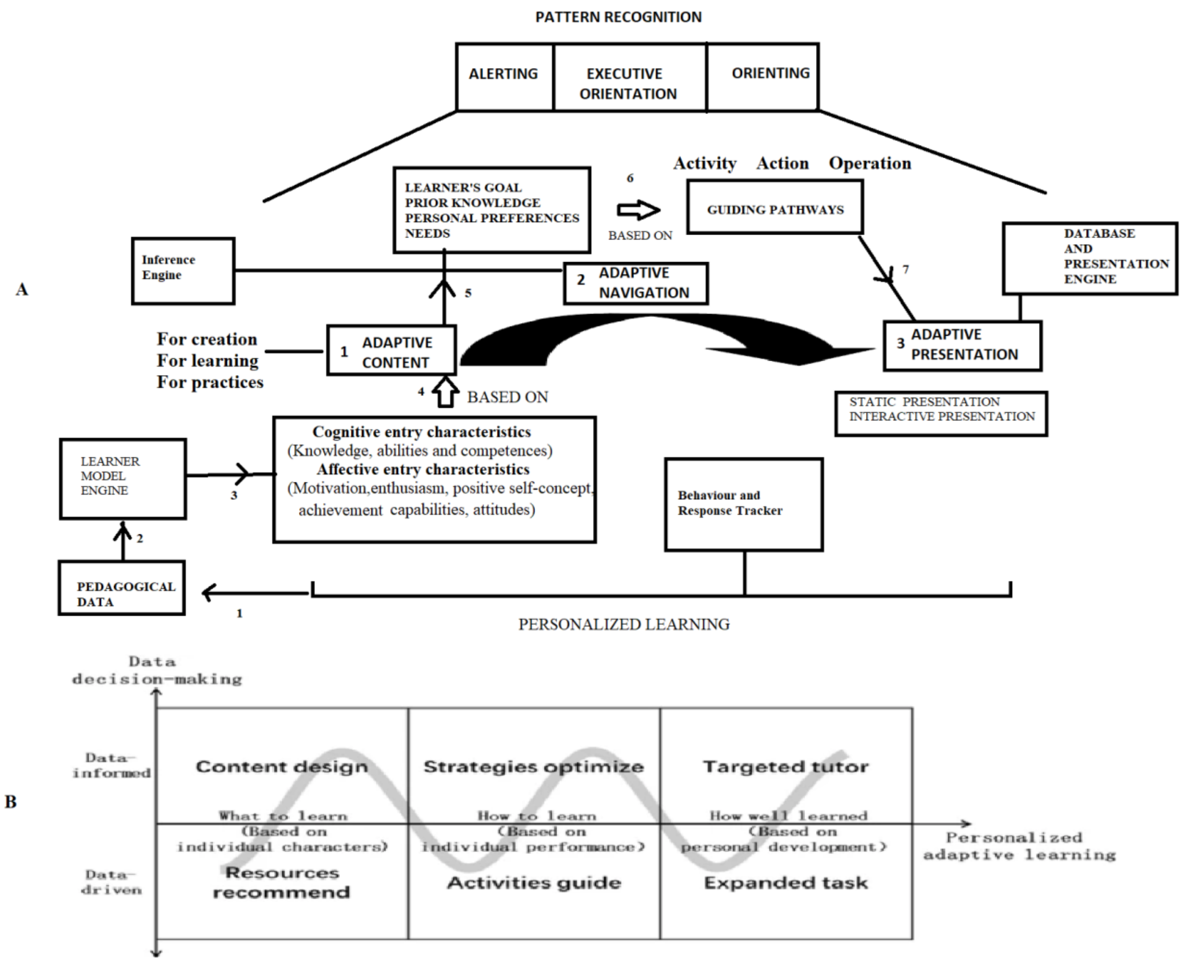
Implementation of Operational Research Analysis Methods in Adaptation Phase

Adaptation is the capacity to change physical or behavioral features to better match the environment. Many studies have proven that using the Adaptive Learning System makes learning more accessible (ALS) (Mampadi, Chen, Ghinea, & Chen, 2011; Nielsen, Heffernan, Lin, & Yu, 2010) Therefore it is a platform that mobilizes both human and artificial actors, allowing for local and distant contact through computer networks. Concerns raised by the design, implementation, and evaluation of these settings are addressed, as are the ramifications for knowledge, individuals, and society. ALS uses three degrees of adaptation: content, navigation, and display. The data from tailored learning activities enter into the adaptation process through cognitive and emotional entry qualities (Hoel & Mason, 2018).

The basic preconditions and restrictions for content adaption are known as cognitive entry characteristics. These include (1) past task learning, (2) preparatory learning, (3) cognitive styles, (4) task-specific skills, and (5) general mediating abilities. Affective entry factors can play a role in content adaption. In addition to motivation, a good self-concept about success capacities and a favorable attitude toward education and learning are required (Fishbacher-Smith et al. 2012). The adaptive navigation function tailors the presentation of links to the learner's objectives, past knowledge, and personal preferences. An adaptable presentation adapts to the learner's or audience's choices and needs. Using these tactics, one may expose a student to the appropriate learning language or layout. Adapting the presentation to make it more relevant (El Janati et al., 2018). A two-dimensional coordinate system may separate six portions of adaptive adjustment teaching methodologies, as shown in Figure 6 (b).

Figure 6

The General Structure of Adaptation Phase (a) The Spectrum of Adaptive Adjustment Instruction Strategies Based on Man-Machine Collaborative Decision-Making (b)



Source: Figure b is adapted from " Personalized adaptive learning: an emerging pedagogical approach enabled by a smart learning environment" by Peng, Ma, and Spector, Smart Learn. Environ. 6, 9 https://doi.org/10.1186/s40561-019-0089-y

The path has three levels as given in Figure 6. Individual characters, individual performance, and personal growth. Every layer has two stages. The individual character layer essentially answers the "what to learn" dilemma. In the individual performance layer, learning is addressed. Here, data-driven decision-making focuses on the activities guide. The personal development layer handles their vision's "how well learned." It predicts whether students can meet their learning objectives by monitoring their progress and proposes more challenging extended projects that match their vision. The layer's data-informed decision-making stage focuses on the problems students face when completing challenging tasks (Peng, Ma, and Spector, 2019). The operational research methods in the adaptation phase can be various ranging from Genetic Algorithms to rule-based adaptive presentation. What is important is that type of the adaptatin can be structured in terms of content, navigation and presentation and different techniques can be used for this. Additionally, it should be noted that a personalized adaptive learning combines customized and adaptive learning. Individual features, performance, personal growth, and adaptive adjustment are fundamental components of customized adaptive learning. As a result of real-time monitoring (supported by smart technology) of learners' differences and changes in individual features, performance, and personal growth, adaptive teaching techniques may be developed.

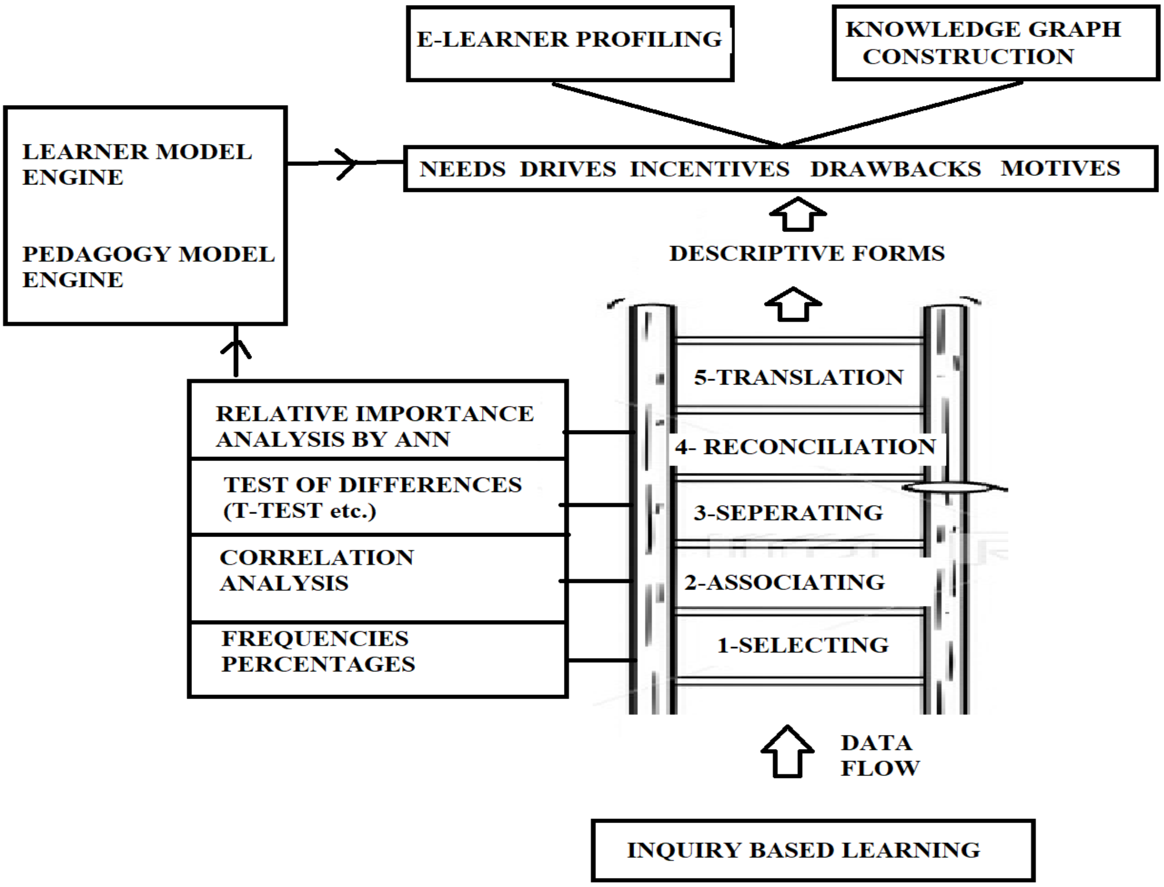
Implementation of Operational Research Analysis Methods in Sensing Phase

Sensing phase is related to descriptive analysis answering the questions of "Why?" (Lepenioti et al 2020). Data aggregation and data mining are two major descriptive analytics methodologies. It is the collecting and structuring of data to create manageable data sets for various applications. Using the previously obtained data sets, data mining recognizes patterns, trends, and meaning. In there needs, drives, incentives, drawbacks and motives are selected, associated, separated and reconciled where the data is taken from preferably inquiry based learning process. Descriptive analytics is used in smart e-learning to describe, summarize, and analyze historical and educational data. Creating e-Learner profiles utilizing personal and historical (dynamic) data. A knowledge graph is a common ontology that conveys a shared idea. These connections are extracted using automated or semi-automated data mining approaches (Tian, Zheng & Chao, 2020). In this phase, descriptive analysis methods (frequencies, averages etc.), correlational analysis techniques, test of differences and relative importance analysis by ANN can be used as an operational research techniques for sensing phase. Many learning systems employ descriptive analytics for analytical reporting. They monitor learner performance to ensure aims and training goals are met. A few examples of how descriptive analytics may be applied in the e-learning can be given as follows (Website 5):

- Analyzing assessment grades and assignments
- Tracking the utilization of learning resources
- Comparing the exam scores of learners
- Analyzing the time required by the student to finish the course
- Collating survey results
- Reporting general trends

The sensing phase concludes with the selection, association, separation, reconciliation, and translation of data from the inquiry-based learning environment into descriptive forms for e-learning profiling and knowledge graph development. Various statistical approaches are used at this phase, which are based on the pedagogic model engine and the learner model engine, respectively (Figure 7).

Figure 7
Sensing Phase

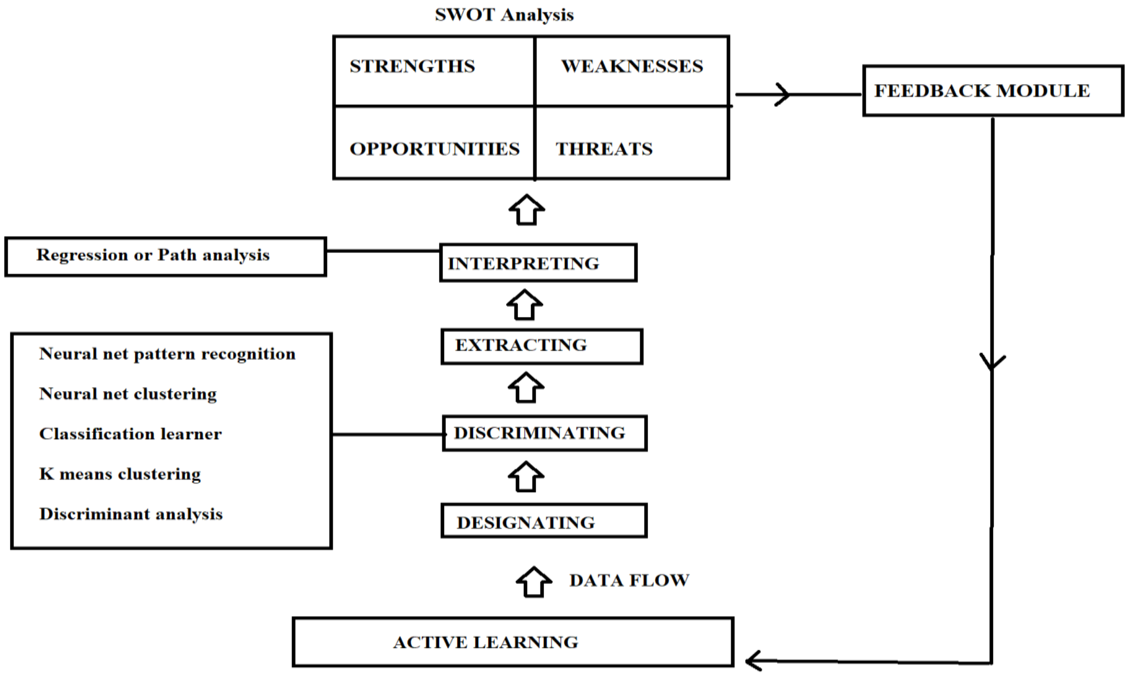


Therefore as seen in Figure 7, the main aim of the sensing phase is to reveal the profile of the learner in terms of needs, drives, incentives, drawbacks and motives and construct a knowledge graph based on this.

Implementation of Operational Research Analysis Methods in Inferring Phase

Diagnostic analytics studies data or information to determine “why did it happen?”. Diagnostic analytics digs deeper into data to better understand the reasons of behaviors and occurrences. Continuous analytics monitors the state of e-learners and resource consumption, decides, and acts autonomously or semi-autonomously. (Tian, Zheng & Chao, 2020). Analytical diagnostics helps find anomalies and causal relationships in data. So, for example, the Classification Learner app in MATLAB trains data recognition models. It may also use supervised machine learning and various classifiers. Examine data, choose characteristics, create validation methods, build models, and assess results. It can also make and train models. A computer can automatically train a categorization model to fit the data. Among other classification models, it may employ decision trees, discriminant analysis, logistic regression, closest neighbors, naive Bayes, kernel approximation, ensemble classification, and neural networks. Finally, path and regression analysis may be used to test causal theories by comparing dependent and independent variables. A causal relationship between variables may be estimated using this technique (Website 6) For the diagnosis of the data, Strengths, Weaknesses, Opportunities, and Threats (SWOT) dimensions can be used as the end product of interpreting all the data. SWOT analysis is an acronym that stands for Strengths, Weaknesses, Opportunities, and Threats. Strengths and weaknesses in this context alluded to internal difficulties that each facilitator (smart curriculum) is responsible for understanding. It is necessary to revisit your strategy to mitigate your shortcomings before implementing your e-Learning method if the sum of your weaknesses exceeds your strengths. Opportunities relate to circumstances that may be taken advantage of as a result of changes in the learning process (e.g., students with a new set of requirements). Threats include everything that might harm the development of the student (Website 7). Figure 8 shows how to make SWOT analysis based on the data from active learning environments.

Figure 8
Inferring Phase



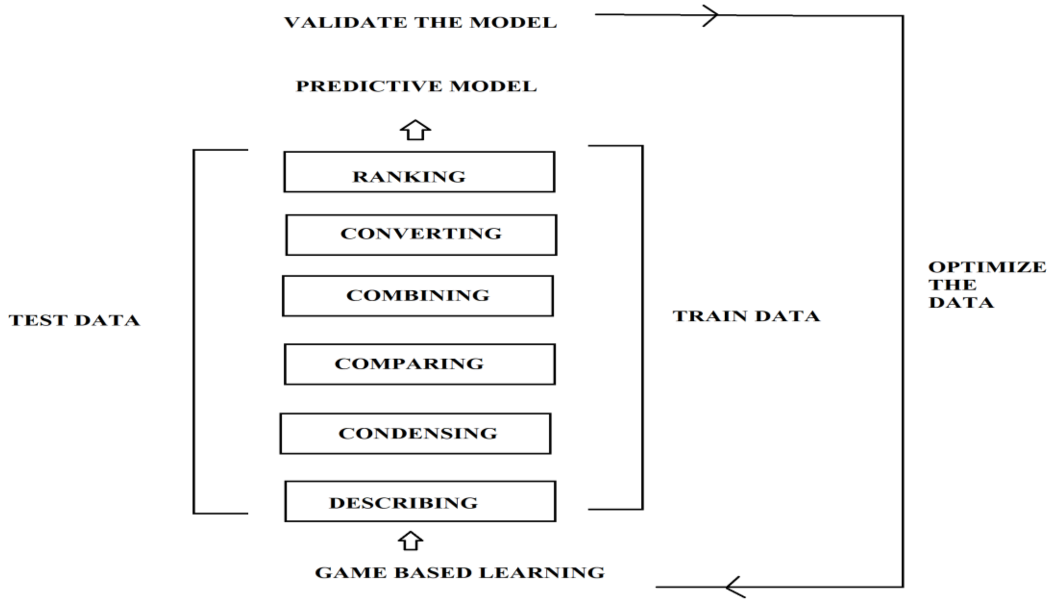
This step involves designating data from an active learning environment to a system so that it can be distinguished using various clustering approaches and the most appropriate and optimum ones can be interpreted using regression or route analysis. Last but not least, they are evaluated to a SWOT analysis, which may be used as a source of information for the feedback module as given in Figure 8.

Implementation of Operational Research Analysis Methods in Self-Learning Phase

Self-learning is the ability of the system to recognize, diagnose and predict patterns, learn from data, and become more intelligent over time. Self-learning smart curriculum uses machine learning techniques on top of advanced neural networks and deep learning frameworks. The capacity of a system to detect, diagnose, and forecast trends, as well as to learn from data and grow more intelligent over time, is referred to as self-learning. A smart curriculum that self-learns is built on top of powerful neural networks and deep learning frameworks, and it uses machine learning methods (Duran, Topal & Korkmaz, 2021).

The information gathered by game-based learning is used to describe, summarize, compare, integrate, and transform information in order to develop a predictive model, which is then used to make predictions. Afterwards, it should be evaluated in order to optimize data based on customer input (Figure 9).

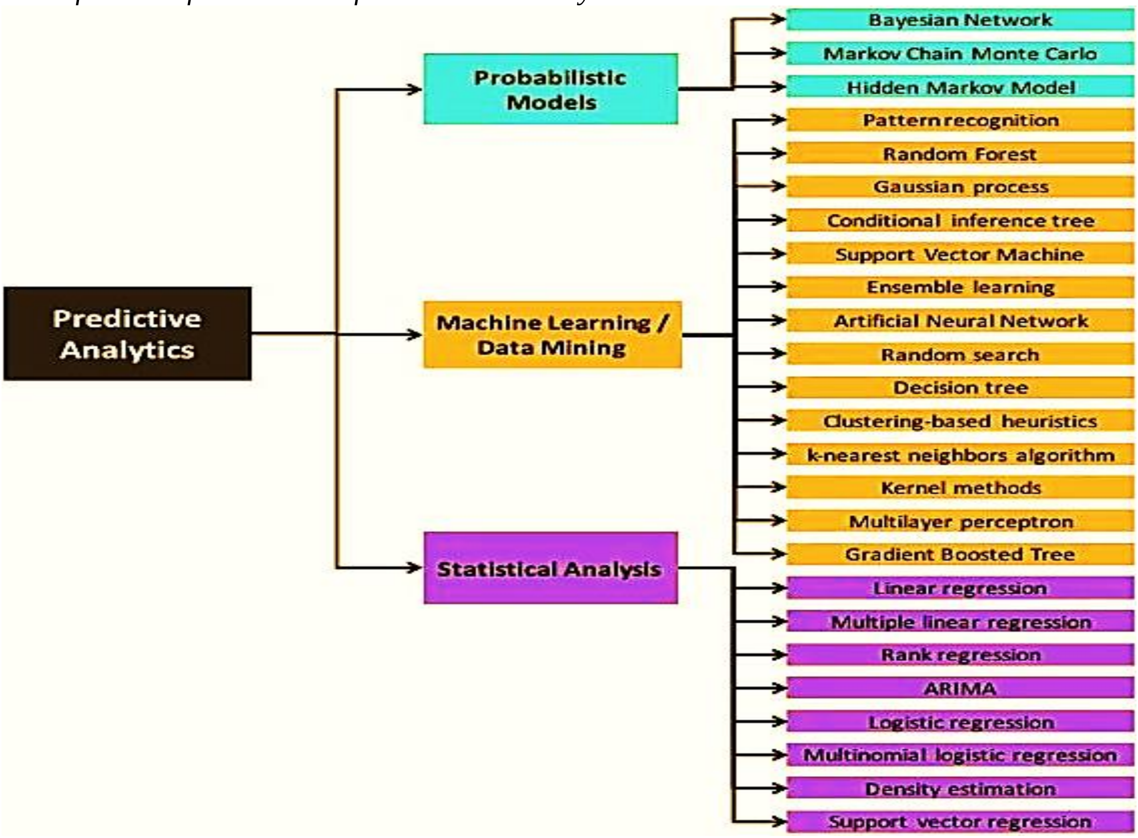
Figure 9
Self-LearningPhase



As seen in Figure 9, the self-learning phase is based on predictive analytics where the main aim is to create a predictive model based on game based learning. Probabilities are utilized in predictive analytics. A combination of data mining, statistical modeling (which predicts outcomes using mathematical correlations between variables), and machine learning algorithms (which include classification, regression, and clustering) is used in predictive analytics. To make predictions, machine learning algorithms, for example, use current data and make best assumptions. Some of the most popular Predictive Analytics Models that can be used in the context of operational research methods are (Henrys, 2021), regression techniques, linear regression model, discrete choice models, logistic regression, classification model, clustering model, forecast model, time series model.

Lepenioti et al (2020) depicts the classification of the methods for predictive analytics answering the questions of “Why?” as given in Figure 10. Predictive analytics are classified in three categories Probabilistic Models, Machine Learning/Data Mining and Statistical Analysis.

Figure 10
Classification of the Methods for Predictive Analytics



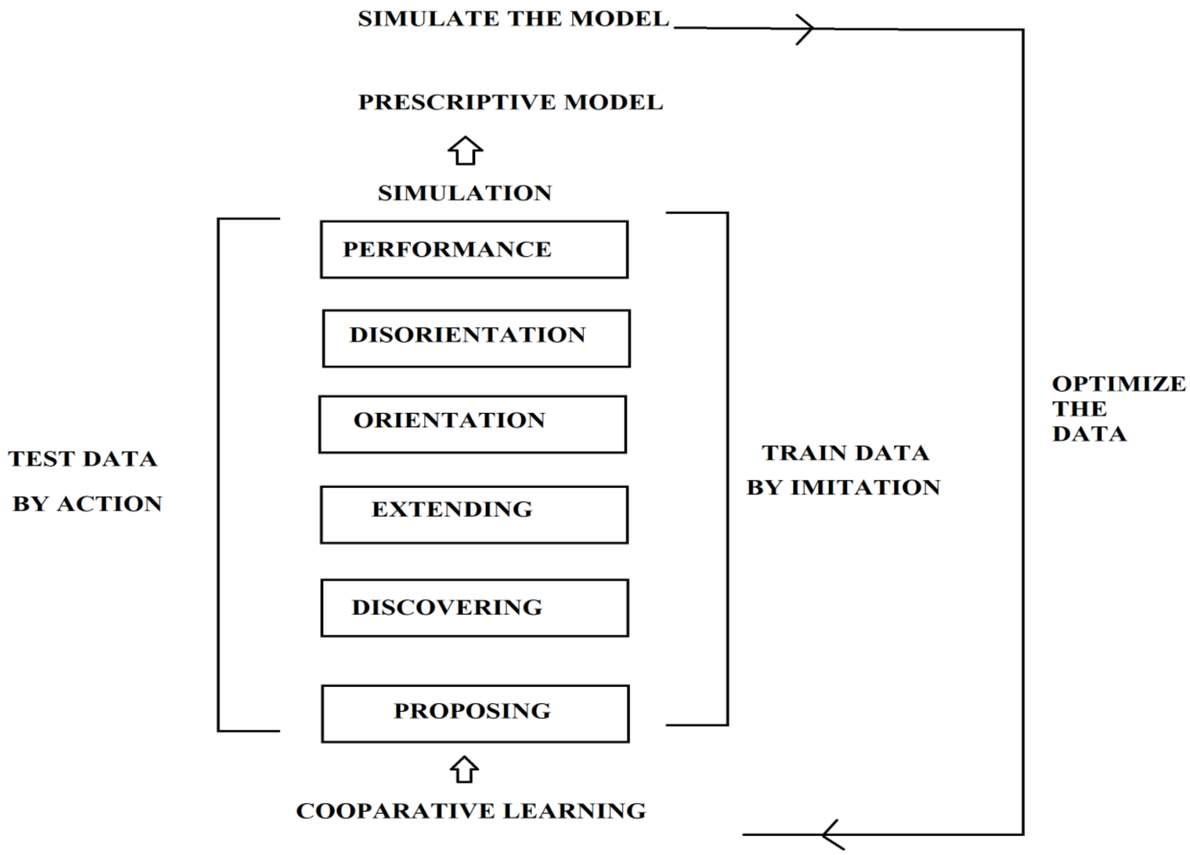
Source: Adapted from " Prescriptive analytics: Literature review and research challenges. International Journal of Information Management” by Lepenioti et al 2020,, *50, 57–70*.doi:10.1016/j.ijinfomgt.2019.04.0

An field of statistical analysis that works with collecting information using different technologies in order to identify links and patterns within enormous amounts of data, which may be used to forecast behavior and occurrences, is called predictive analytics. In there there are three main kind of predictive analytics as statistical analysis, machine learning or data mining and probabilistic models (Figure 10). Using three type of predictive analytics, we can forecast the future based on data.

Implementation of Operational Research Analysis Methods in Anticipation Phase

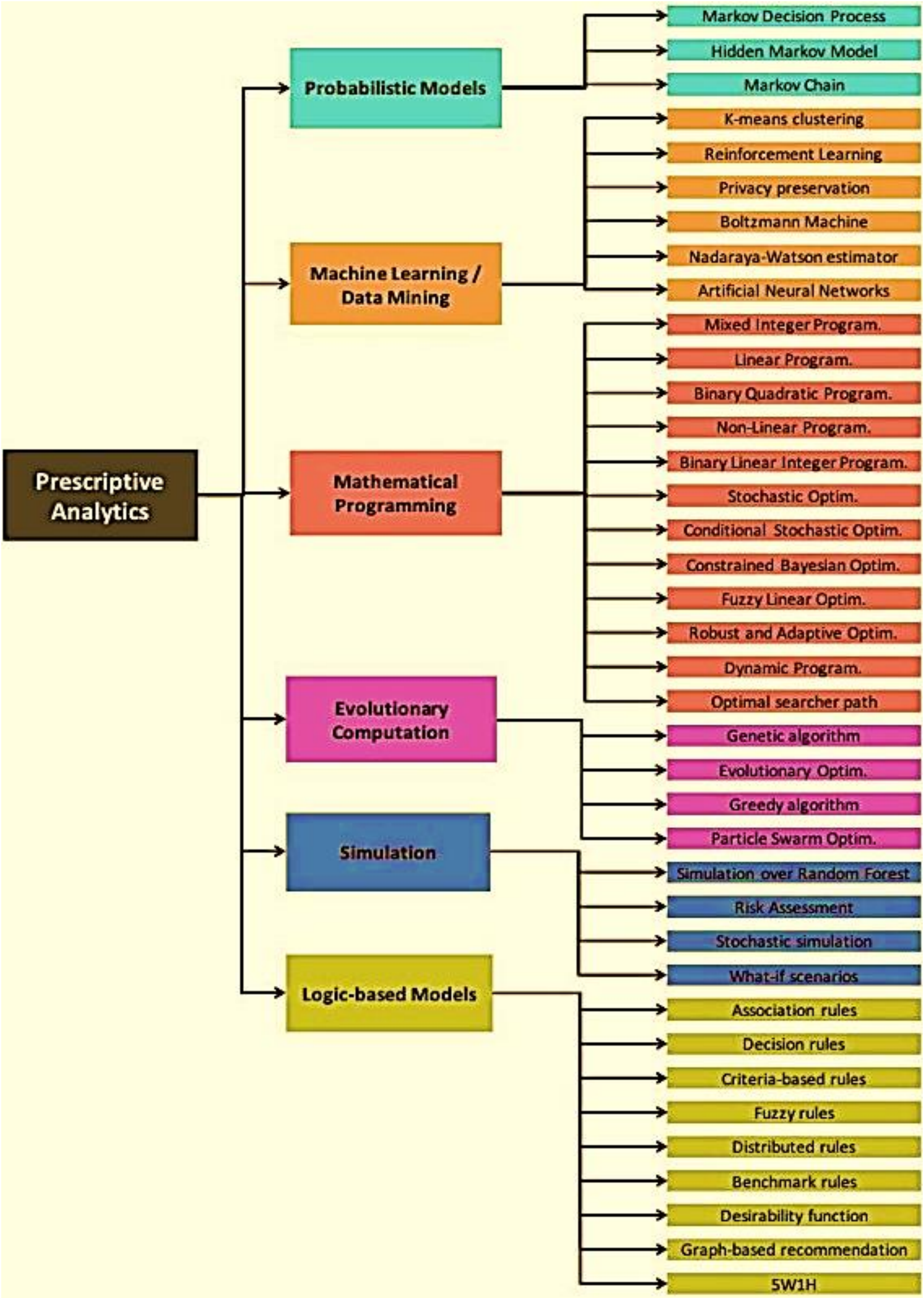
The anticipation phase is related to the action and performance of an individual in cooperative learning environments. In there, students are supposed to propose, discover and extend what they learned and orient and disorient their previous knowledge through actions into performance to enable the system to create a prescriptive model in the simulation until it optimizes the model in the simulation (Figure 11).

Figure 11
Anticipation Phase



As shown in Figure 11, the anticipation phase is mostly related to prescriptive analytics. Prescriptive analytics seeks information that can help choose the best course of action in a given situation. Lepenioti et al (2020) depicts the classification of the methods for prescriptive analytics that can also be used in the anticipation phase given in Figure 12.

Figure 12
Classification of the Methods for Prescriptive Analytics



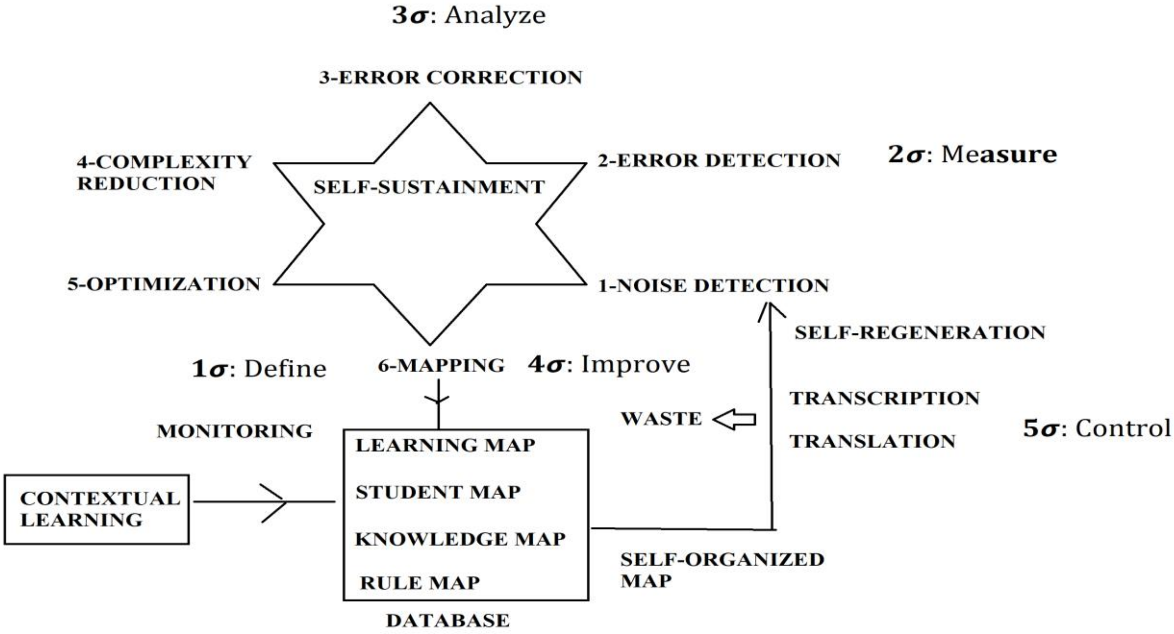
Source: Adapted from " Prescriptive analytics: Literature review and research challenges. International Journal of Information Management" by Lepenioti et al2020,, *50*, *57–70*.doi:10.1016/j.ijinfomgt.2019.04.0

The simulation model can be best suitably used for the anticipation phase in the smart curriculum paradigm (Figure 12). Simulation is the process of generating a computer model of a real-life or imaginary event to test the system. Changing variables in mathematical models enables for prediction of system behavior and decision making. Prescriptive analytics uses simulated decision-making to improve the effectiveness of human or software-based judgements (Lepenioti et al. 2020).

Implementation of Operational Research Analysis Methods in Self-Organization Phase

Self-organization is related to self-sustainment and self-regeneration of the self-organized map of the smart curriculum. Self-sustainment refers to any combination of hardware and software that can detect faults, inefficiencies, and other issues in its behavior and resources, and correct those problems on the fly (Website 8). Therefore, such a system should have noise detection, error detection, error correction, complexity reduction, optimization, and mapping features for self-sustainment purposes. In the end, it creates its self-organized map consisting of a rule map, knowledge map, student map, and learning map. The main data in there is from contextual learning environments given as Figure 13. Self-regeneration refers to self-healing characteristics based on the transcription and translation of a self-organized map to get rid of undesired waste.

Figure 13
Self-Organization Phase

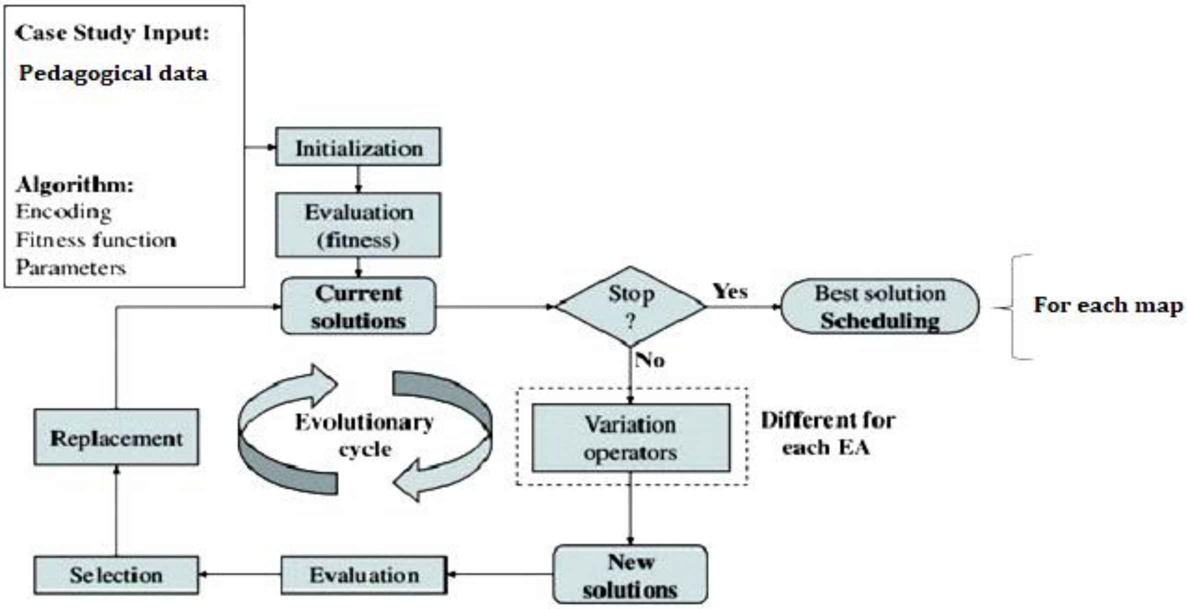


Decision-making methods are at the core of self-organization phase in this regard because the study of decision theory is concerned with how we make use of our freedom. There are alternatives to select from in the scenarios discussed by decision theorists, and we make our choices in a non-random manner. In these cases, our choices are acts that have a certain outcome in mind. The study of goal-directed behavior in the context of alternatives is therefore referred to as "decision theory." We do not make decisions on a constant basis. The history of practically every activity reveals periods during which the majority of decisions are taken, followed by periods during which the majority of implementation takes place. The decision theory attempts to shed light on the former sort of time in a variety of different ways (Pokrovsky, 2009). The operational research approaches give quantitative data to make decisions, which assists the analyst in making the best choice possible, resulting in the maximization of profits and the minimization of losses for the organization (Singla, 2016). In the self-organization phase the algorithm is based on the lean six-sixma methodology (Figure 13). When it comes to quality improvement, Lean Six Sigma is a fact-based, data-driven mindset that places a higher priority on defect prevention than defect detection. The reduction of variation, waste, and cycle time, as well as the promotion of work standardization and flow, leads in increased improved bottom-line outcomes.

In this respect, various operational research techniques in previous phases can be used in this phase as well. However, we recommend evolutionary computing approaches in this phase. A subfield of artificial intelligence and soft computing that studies evolutionary computation is defined as follows: evolutionary computation is a family of algorithms for global optimization that are inspired by biological evolution, and evolutionary computation is the study of these algorithms. In technical words, they are a class of population-based trial and error problem solvers with a metaheuristic or stochastic optimization flavor to their approach to problem solving (Sen, 2015). An initial collection of possible solutions is established, and this set is repeatedly modified during the process. Each new generation is created by stochastically discarding less desirable solutions and injecting minor random modifications into the existing ones. In the domain of predictive analytics, evolutionary computing is used to solve complicated issues in data-rich situations where accurate answers cannot be determined using mathematical formulae (Lepenioti et al. 2020). In the field of heuristic search, evolutionary computing approaches, which are based on a strong evolutionary principle known as "survival of the fittest," are a particularly fascinating subset. Natural processes such as genetic inheritance and the Darwinian struggle for survival are modelled by stochastic algorithms used in evolutionary computing approaches (Michalewicz et al. 1997). EAs that have been chosen for this study have used an evolutionary process that is shown in Figure 14.

Figure 14

Typical Optimization Scheme of Evolutionary Algorithms



Source: Adapted from "Demand Response of Residential Houses Equipped with PV-Battery Systems: An Application Study Using Evolutionary Algorithms" by Lezama et al2020, *Energies*. 13. 2466. 10.3390/en13102466.

Initially, a fitness function and solution encoding are defined for a given challenge in Figure 14. The EAs operate on an iteratively updated population of alternative solutions stored as vectors. The way EAs create new solutions from the beginning population sets them apart. The fitness function is used to assess solution performance. Experimental data shows that a population will ultimately progress towards an optimal fitness value based on natural selection principles (Lezama et .al. 2020).

Implimentation of Operational Research Analysis Methods in Feedback Phase

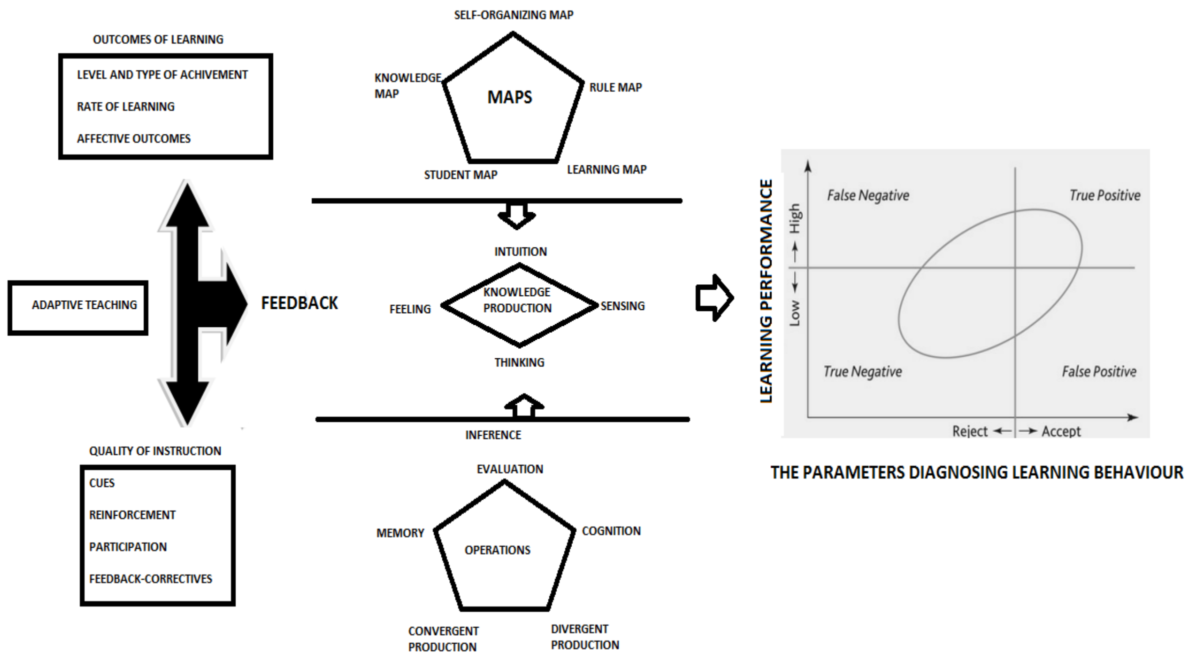
Feedback phase is related to the ability to give a proper feedback to sustain self-organization and self-learning of the whole smart system. Feedback phase is based on adaptive learning and the results of the all data during other phases. Feedback parameters regarding the quality of education are the cues, reinforcement, participation and in-class feedback and corrections that are based on the quality of instruction containing four constituents in the Bloom's Mastery Learning (Tenenbaum, 1989; Bloom, 1976). Cues relate to any and all information that is provided throughout the presentation and explanation of the learning activity in question. The majority of them are verbal, however there are several that are also graphical. Participation is associated with the efforts put forth in order to complete a task or with the participation in a task. Participation is often represented in terms of active learning time, which is measured on a regular basis. Bloom (1976) maintains that participation or active learning may take either surreptitiously (relating to internal thinking processes) or openly (referring to external thought processes) (i.e., as observable interactions with learning material). Reinforcement refers to the teacher's affective reactions to a student's conduct, which may include praise, criticism, encouraging or discouraging words. Successful reinforcement is dependent on the particular learner, his or her progress, and the complexity of the job to be learned in order to be effective (Fischbacher-Smith et. al. 2012).

There are two data flows in the feedback phase. One is from the data from all the phases and the other is the pedagogical data from adaptive learning. Adaptive learning is an educational system that offer personalized materials and learning activities. Adaptive learning is a personalized, technology-based teaching strategy that is used to instruct students. This methodology ensures that all students have equal opportunity to achieve, regardless of their learning styles, learning speed, or personal preferences, among others. A student's performance and reactions to digital material may be examined in real time using adaptive learning systems, and classes can be adjusted as a result of the information gleaned from the students' responses. Suppose a student continues to struggle with a certain topic or lesson. The network will "take note" of this and tailor the learning experience to match the student's specific requirements in that subject or lesson. Adaptive learning systems use a variety of technologies, including artificial intelligence (AI), streaming and archival video, immersive mixed reality, and gamification systems, to provide a more personalized learning experience. However, the simultaneous usage of these bandwidth-intensive apps causes a larger pressure on the network, which is exacerbated by the rise in remote learning, educational, and home networks networks in general (Website 10). It is critical to understand the on-line learning habits of students in order to deliver successful adaptive learning on computer networks. A system for diagnosing on-line learning behavior was proposed by Hwang (1998), and several parameters were defined and recorded to describe the on-line behaviors of students. These parameters included idle time, response time, effective teaching and learning time, ineffective teaching and learning time, and log-in time. A variety of student learning attitudes may be detected using these criteria, including "concentration," "willingness," and "patience," and the course content can be customized to fit each student's specific needs as a result (Tseng et al 2008).

When it comes to the results of learning which is related to the main aim of feedback, Bloom differentiates between (a) the amount and kind of accomplishment, (b) the rate of learning, and (c) the affective consequences of the learning. The nature of accomplishment is defined by the aims and content of the tasks that are completed (Fischbacher-Smith et. al. 2012). The main aim of the feedback mechanism is to use maps and make inferences regarding the operations defined by Guilford's Structure of Intellect (SI) theory, as cognition, memory recording, memory retention, divergent production, convergent production, evaluation. Cognition refers the ability to understand, grasp, discover (Figure 15).

Figure 15

Feedback Phase



Source: Right figure Adapted from " Introduction to Industrial/Organizational Psychology" by Riggio. 2017, Routledge, USA

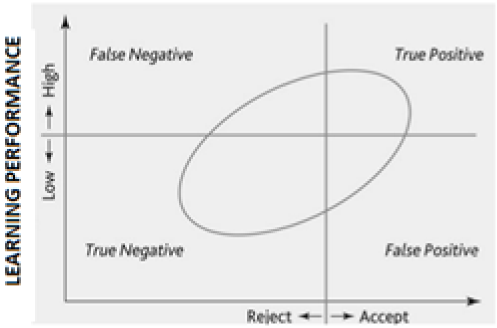
Memory refers the ability to remember information in Figure 15. Evaluation refers the process of assessing whether a response is correct, consistent, or valid. Divergent production refers the process of creating multiple solutions to a problem. Convergent production refers the process of determining a single solution to an issue. Through these operations, the system classify the knowledge in terms of four basic functions: thinking (T), feeling (F), sensing / sensation (S) and intuition (N) proposed by Carl Jung.

Primary aims in this procedure are to maximize the likelihood of accurate selections in choosing the correct behavior of student candidates and to ensure that the decisions are done in a manner that is free from both deliberate and inadvertent prejudice against these applicants. In an ideal circumstance, we want to support the desired and positive behaviors of the individuals who will be successful and reject the undesired ones. In fact, however, some errors might be involved. In the context of diagnosis, a false-positive error occurs when an individual without a disease is "identified" by a diagnostic test as having the disease (Turner, 2013). When the instructor or the system erroneously accept the unwanted behavior, we are producing false-positive errors. On the other side, when the system erroneously reject the desired behaviours, we are producing false negative errors (Figure 16 left). Although both errors are troublesome to the system, it is more difficult to uncover false-negative errors than false-positive errors. We cannot remove these mistakes totally, but we may lessen them by employing more objective choice procedures. The system can utilize a statistical decision-making model such as multiple regression model, which combines information for the selection of behaviour in an objective, planned method. Each piece of information about studen is given some ideal weight that shows its strength in forecasting future success (Jekel, Katz, Elmore, & Wild, 2007; Riggio, 2017).

Finally, game theory may be utilized to objectively assess student behavior. Game theory is a branch of applied mathematics that studies situations in which parties, called players, make interdependent decisions. This dependency forces each player to examine the other's potential alternatives, or strategies. A game's solution outlines the optimum behaviors of the players, who may have similar, opposing, or mixed interests. Game theory has been used to a wide variety of situations where players' choices influence the outcome. The theory both supports and goes beyond the classic theory of probability by emphasizing the strategic components of decision making (Website 11). For example, the parameters diagnosing learning behaviour and learning performance can be modeled by 2×2 games. “A general (symmetric) 2×2 game is determined by the payoff matrix (for the column player) indicating the payoffs for the player's joint decisions. The rank ordering of the four payoff values *R, S, T, P* determines the characteristics of the game. Without loss of generality we may assume $R > P$ (if this does not hold, we simply interchange *C* and *D*) and normalize the payoff values such that $R = 1$, $P = 0$ holds.” (Figure 16 right) (Website 12).

Figure 16

*General 2*2 Game Can Be Used in the Feedback Phase For the Diagnosis of Learning Behaviour and Performance*



THE PARAMETERS DIAGNOSING LEARNING BEHAVIOUR

		Row player	
		C	D
Column player	C	R	S
	D	T	P

A GENERAL 2*2 GAME

Source: Adapted from https://www.univie.ac.at/virtuallabs/TwoByTwo/ retrieved from 06.12.2021
Source: Right figure Adapted from " Introduction to Industrial/Organizational Psychology” by Riggio. 2017, Routledge, USA

The core of many human and animal interactions can be described by so-called 2×2 games. These games are paired encounters between persons with two behavioral alternatives which can be defined as strategies given in Figure 16. Parametes can be chosen to create collaboration, competition or synchronization. The prisoner's dilemma is a well-known example of how to explore and explain the origins of altruistic cooperative behavior among strangers and selfish individuals.

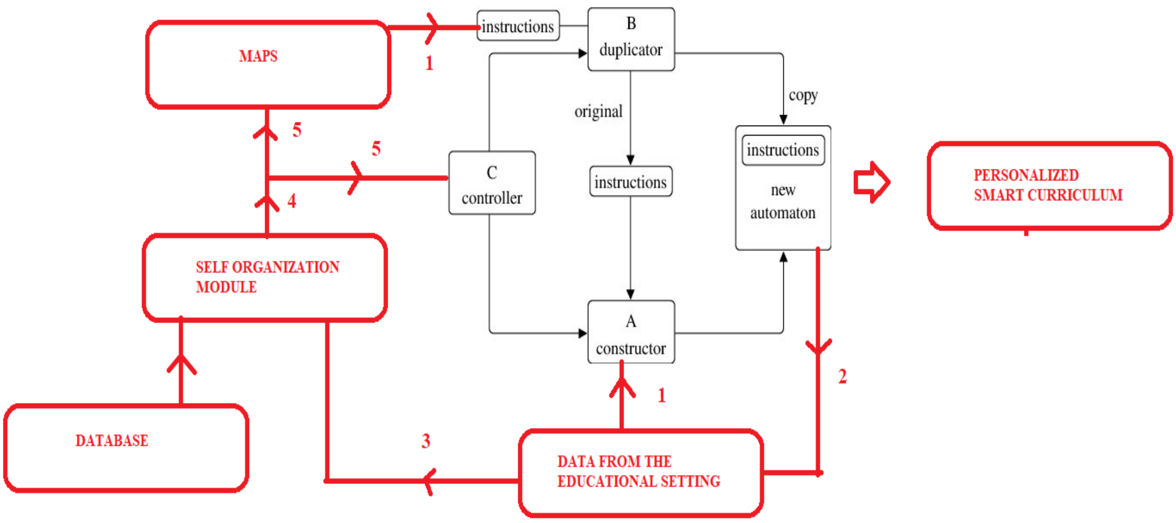
Discussion and Conclusion

A smart curriculum can be defined as a new type of curriculum having the features of adaptation, sensing (awareness), inferring (logical reasoning), self-learning, anticipation, and self-organizations and restructuring feedback so as to adapt itself the various differentiated instructional methods. In this context, we theoretically illustrate how to integrate algorithms and methodologies based on intelligence theories in the smart curriculum development process.

Finally, smart curriculum is very distinctive from classical educational technologies since it has a smart and self-learning feature so that it can self-regenerate or self-replicate. It was von Neumann who initially introduced the idea of a self-replicating artificial system, back in the 1940s. John von Neumann came up with the notion of a universal constructor, which is an abstract machine capable of self-replication by following a set of instructions, utilizing external construction blocks, and consuming energy. Only cellular automata1 have been used to simulate and test the behavior of Universal Constructors to this point in time (Lavickova et al. 2020). Although such a system is too complicated for a smart curriculum it is worthy to consider these characteristics as well. A landmark study by von Neumann, The Self-Replicating Automaton, addressed the logical circumstances under which an abstract—but embodied—automaton might be capable of reproducing itself. Fully computational approaches were used throughout: the replicating system was considered as an automated machine that could be programmed to do certain tasks. The answer that was discovered was both original and imaginative. Figure 17 depicts a simplified representation of the fundamental concept. The fundamental building blocks are identified here, and they include the following (Solé et al2007): the constructor (A), who is capable of creating a physical new system by using the raw materials accessible in the surrounding environmen, the blueprint or set of instructions that convey information about the tasks that must be completed by the constructor, a duplicator (B) that accepts the instructions and precisely copies them, and , the controller (C) is responsible for ensuring that the whole process proceeds in a predetermined order.

Figure 17

The Logic of the Self-Reproducing Machine: Von Neumann's Self-Replicating Automaton Components Closely Related to Those Found in Living Cells



Source: Modified from " Synthetic protocell biology: from reproduction to computation. Philosophical transactions of the Royal Society of London. Series B, Biological sciences" by Solé et al2007, *Biological sciences, 362(1486)*, 1727–1739. https://doi.org/10.1098/rstb.2007.2065

The logic of the self-reproducing machine proposed by von Neumann can be applied to smart curriculum but the physical requirement and engineering of such a system requires very collective and technical backup. In this regard, a smart curriculum has the features of von Neumann machine and it can be modified and extended in a form of smart curriculum which can replicate itself to personalized one. The red boxes and lines are the extension of the original model. In this modification the main source of the source of the smart curriculum is the data and information from educational experiences from the individual and his/her responses and the provision of such experiences from the system based on database, maps. As the data is processed from data to idea, the smart curriculum integrate it via its database and maps and finally re-arrange and re-produce itself as a individualized curriculum based on the needs, interests and other characteristics of the student. Therefore, a smart curriculum is a self-directed curriculum in terms of being knowledge manufacturer rather than knowledge presenter, intelligent because of self-conducted learning system and experience-centered due to taking the real lively data from educational settings. It is flexible because it is sensitive to personal preferences, it is adaptive with regards to the level and traits of the student. It has also technology embedded structure offering desired learning experience regardless of time and place (Park, Choi & Lee, 2013).

There is a long way to go before the physical implementation of a smart curriculum using present technologies. In contrast, as technology progresses, it becomes simpler to design a curriculum that includes smart elements. A smart curriculum may also employ human resources when some of the technology's characteristics can't be integrated into the complete operational mode of the smart curriculum. As a result, future research should focus on how to include physical structure into such an innovative curriculum. New theoretical research are also required to better understand this system.

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