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# A Systematic Review of Process Modelling Methods and its Application for Personalised Adaptive Learning Systems

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## ABSTRACT

*This systematic review work investigates current literature and methods that are related to the application of process mining and modelling in real-time particularly as it concerns personalisation of learning systems, or yet still, e-content development. The work compares available studies based on the domain area of study, the scope of the study, methods used, and the scientific contribution of the papers and results. Consequently, the findings of the identified papers were systematically evaluated in order to point out potential confounding variables or flaws that might have been overlooked or missing in the current literature. In turn, a critical structured analysis of the studies was done in order to rate the value of the stated works and the outcomes. Theoretically, the results of the investigated papers were summarized and empirically represented, in order to help draw conclusions as well as provide recommendations for future researches. Indeed, the investigations and findings from the papers show that one of the key challenges in developing personalised adaptive intelligent systems for learning is to build an effectively represented users profile, learning styles or objects, and behaviours to help support reasoning about each learner. Perhaps, the resultant information systems need to be able to describe and support real world (i.e. semantic or metadata) interpretation about the different learners, and provide effective ways to adapt the information about each user based on the existing knowledge or data especially as it concerns references to and/or discovery of the different patterns that can be found within the knowledge-base.*

**KEYWORDS:** Process mining, Adaptive learning systems, Process modelling, User profiles, Personalisation, Systematic review

## INTRODUCTION

Over the past few decades, it has been shown that one of the key challenges in developing personalised adaptive system for learning is to build an effectively represented user's profiles, learning styles, patterns and/or behaviours to help support reasoning about each learner (Nganji et al, 2011; van Velsen et al, 2012; Okoye et al, 2018). Moreover, Badidi et al (2018) note that the *personalisation* of e-content aims to improve the intended user's experience by adapting the system to meet individual preferences and contexts through the following key elements:

- Collection of information about users (e.g. current activities, preferences, location etc.)
- Predicting user's requirement through the ability to make recommendations.
- Provision of user-centric service and/or satisfaction (e.g. through accessibility, trust, performance, and loyalty) (Fan et al, 2015, Okoye et al, 2014)

To this end, the work in this paper focuses on carrying out a systematic analysis of relevant literature towards the development of an intelligent system for learning particularly through adaptive detection of changes in patterns and/or behaviour of the different users (e.g. the case study of people with attention deficit hyperactivity disorder). Moreover, the methodology of this paper through the means of process mining is all aimed at determining which learning content is best suitable or required progressively through time. In fact, the aim of this review is on finding suitable methods and supporting the provision of personalised adaptive learning systems for the learners through the systematic process analysis method proposed in this paper. Essentially, the work focuses on review and investigation of the implications of available researches and/or methods that trails to either:

- Monitor changes in patterns or behaviours to help infer the learner's learning process or underlying knowledge-base. For instance, by capturing an event or activity during the learners interaction within the learning environment.
- Track learners activity executions and progress.

- Provide learning guidance and paths based on content similarities or background (user profile) in order to determine the learner's interest.
- Define rules that determine which content will be shown or defined for a particular user (e.g. pattern recognition)
- Provide feedback as to how best to make adjustments to increase the user's motivation to learn (i.e. prediction and recommendation systems) and perform newly tasks efficiently with a higher level of consistency and effectiveness.
- Increase the rate of learning for users (e.g. with ADHD) to a significant level.
- Reduce the amount of time and resources being utilized during the learning process.
- Provide methods and/or tools that can be applied to increase user's motivation to learn, and in turn, results to personalised adaptive learning systems.

Indeed, the systematic method of analysis in this paper (which integrates the York method - *planning, reviewing, and disseminating*) (Van Velsen et al, 2008) looks at the need for using the personalised adaptive systems to manage the learning process. The main focus for applying the method is to search the literature for the most relevant papers in the area of personalised adaptive learning systems in order to help identify the current opportunities and challenges. Moreover, the methodology of this paper allows us to bring to knowledge the current trend and/or what is missing in the research domain (i.e. personalised adaptive systems). As a result, the work discusses ways towards bridging the gap between an effective utilization of the learning systems and the users respectively, for instance, learners with ADHD and so-called non-disabled learners. In fact, the review was undertaken to investigate the effectiveness of using such method (i.e. personalised adaptive systems) in the management of the learning process for different users. Basically, the process involves a systematic review of the literature within the field of e-learning and personalisation, context-aware systems, adaptivity, and process mining. Likewise, the method points out the key hypothesis or notions that support the various topic areas by identifying the relevant (or topmost) papers as well as the type of evidence available in the literature or that have not been reviewed comprehensively before.

On the other hand, the review was carried out as a foundation or guideline towards achieving the aforementioned aims and stated targets in this paper. Obviously, to manage and guide the research analysis, the papers and approaches suggested were clearly grounded on evidence rather than expertise in order to ensure the objectives or goals are met. Accordingly, the quality of the review work is achieved in line with other studies (Higgins & Green, 2010) which suggests that the evidence-based paradigm for review quality should be measurable, visible, objective and verifiable.

The rest of the paper is structured as follows: in the **Theoretical Background** section - appropriate related work is analysed and discussed as a preliminary towards an intuitive understanding of the motives and scope of this work. This is followed by highlighting the criteria for analysis or investigation metrics in the **Review Metric** section. Next, the work introduces the **Methodology** of the paper which includes the procedures and search methods for the available literature. In addition, a description of the database of e-journals, documents, and indexing used to retrieve the selected papers were also introduced in this section of the paper. The **Systematic Analysis of the Review Results and Outcomes** section presents the results and the thematic table for the selected papers and also expounds on the relevance of the different works to the main aim and objectives of this paper. The significance of the findings from the available literature was discussed in more details in the **Discussion** section. Finally, the **Conclusion** section concludes the paper and points out directions for future research.

In summary, this article structures and presents the paper and its results in the following order:

- 1: Theoretical Background.
- 2: Review Metrics
- 3: Methodology
- 4: Systematic Analysis of the Review Results and Outcomes
- 5: Discussion of Results and Outcome
- 6: Conclusion and Future Works

## THEORETICAL BACKGROUND

The *personalisation* of contents (e.g. in cloud computing or related services such as the e-learning systems) are the emerging trends (Badidi et al, 2018). The authors in Badidi et al (2018) notes that the main focus of the *personalised adaptive systems* is to create and provide a flexible (dynamic) customized content that matches the user's preferences or profiles. For instance, an e-learning system may suggest the

best path or curriculum a specific learner could follow in order to complete the learning process in time and/or with good performance.

Riecken (2000) is even more specific about the definition of personalised adaptive systems. According to the author (Riecken 2000), *personalisation* is about understanding the needs of each individual user and helping satisfy a goal that efficiently and knowledgeably addresses the individual's need in a given context. Equally, Hagen et al (1999) note that personalisation is the ability to provide content and services that are tailored to individuals based on knowledge about their preferences and/or behaviour.

Indeed, in recent years, there has been a combination of factors that affect learners experience with information systems such as the e-learning systems including - the level of efficiency in use and effortlessness in learning, lack of satisfaction with the system, confusing navigation, slow in loading and download time, frequency of errors and difficulty for first time users in learning the interface quickly etc. Moreover, there is evidence that in the design of personalised adaptive learning systems that it is essential to define the user's goals and to specify the intended context of use (Okoye et al., 2014). In theory, Okoye et al, (2014) put forward a novel framework for user-centered design practice that enables a deeper understanding of the user requirements. Interestingly, through evaluation of collected facts and the quantitative analysis method: the authors proposed and implement a solution to the dynamic web accessibility issues for a particular users group by designing and deploying a software application, and its implementation for best practice that informs developers on how best to significantly and effectively approach the design of personalised adaptive systems/applications.

In another research, Okoye et al (2014a) used the idea of process mining to discover, monitor and improve the set of recurrent behaviours that can be found within a learning process. The work utilized the technique in order to address the problem of determining the presence of different learning patterns within an existing learning knowledge-base.

According to Huang and Shiu (2012), searching for suitable learning paths and content for achieving a learning goal is time-consuming and challenging especially on dynamic learning platforms. To tackle these problems, the authors propose a User-Centric Adaptive Learning System (UALS) that uses sequential pattern mining to construct adaptive learning paths based on users' collective intelligence and recorded events and then employs Item Response Theory (IRT) with a collaborative voting approach to estimate learners' abilities for recommending adaptive materials.

Likewise, this paper focuses on determining the best methods towards provision of effective and suitable personalised adaptive learning systems for the users. In fact, the systematic review unlike many of the existing methods/works focuses on - how the personalisation, as well as effective integration of the process mining and/or modelling methods can be used to manage and improve the learning process with the users (e.g. learners) in mind.

## REVIEW METRICS

Primarily, this work explores the best possible ways towards addressing the following research criteria or investigation metrics. Thus:

- C1.** What areas/methods for process modelling and its application in real-time addresses the personalisation of adaptive learning systems? and what sort of opportunities has been made available in these areas?
- C2.** How have evaluations of personalised adaptive learning system been carried out in existing literature? and how can the potential flaws in the findings be improved? (e.g. using the process mining and modelling tools or techniques)
- C3.** Which methods, prototypes or tools have been used?
- C4.** Which variables (in terms of the evaluation or search metrics) have been assessed in the past?
- C5.** What other related methods have been used in designing of the systems? and what are the validity as well as the reliability of the used/proposed approaches?
- C6.** What are the strength and weaknesses of those approaches? and/or the current trends?
- C7.** What is missing? and if possible, what are the most important areas relevant to this work and future research?
- C8.** How can we create a new framework for practice? or if needed modify an existing one that could help harness the findings and address those challenges as identified?

## METHODOLOGY

The methodology of this review work is based on the York method (Van Velsen et al, 2008; Centre for Reviews and Dissemination University of York, 2001). According to Van Velsen et al (2008), the York method is a technique for conducting systematic and empirical literature reviews with its origin from the medical science (Hidalgo et al, 2011; Meo et al, 2010, Centre for Reviews and Dissemination UY, 2001), The work in Van Velsen et al (2008) notes that the method can be applied in any given context with small modifications (e.g. leaving out descriptions of medical interventions). Moreover, the method has proved to be effective in analysing a collection of reports or documents in any specific area of interest (or search term) in order to draw conclusions especially based on some pre-defined evaluation criteria. Specifically, the work of the Centre for Reviews and Dissemination, UY (2001) defines the York method as a framework for carrying out systematic reviews described in three stages - *planning*, *reviewing*, and *disseminating*. Likewise, the method in this paper makes use of the York method with slight variations by taking out the medical aspects or descriptions (particularly as it concerns the technological aspect which this work considers) for the purpose of this study and the results analysis.

### *The Review Method & Procedures*

First, the work creates the terms (search metrics) which is used to search for related papers in the literature. In turn, the results of the search terms for the original search were used to look for further evidence. Practically, the marginal borderline of the search process was scoped (contextualised) in line with the steps and definition in (Hidalgo et al, 2011) as follows.

The work:

1. Selected and recorded appropriate search engines that were used to expand the search terms.
2. Query those search engines with the initial search terms.
3. Select, say, the first ten documents found as relevant papers.
4. Then extract all the analogies, definitions, and different terms referred to by each search term or concept in the selected documents.



5. Add those concepts to the list of search terms.
6. Repeat for an acceptable number of iterations until the new terms dwindle.
7. Lastly, keep track of the semantic relatedness or relationships (metadata) as well as use a table to structure and present the derived information from the search engines in a matrix format, thus, document the results for further analysis.

Secondly, besides databases, the work also looked at other sources and websites of existing e-learning tools and methods as well as well-known researchers. Specially, the work researched the e-learning products, existing publications and blogs for relevant information within the field of process mining and personalised adaptive e-learning systems.

Consequently, the following inclusion criteria were used for the further search and review process:

1. The studies have to report the evaluation or design of an e-learning and/or personalised adaptive learning system.
2. The evaluation of the system has to be user-centric or partly focused on process mining and modelling technique.
3. The study has to describe and discuss at least one of the following criteria: validity or structural method of inquiry, contribution to knowledge, design methods/approaches used, the variables assessed, the implementation of results that fit in any of the noted fields - *domain area, scope, tools used, the scientific contribution of the papers and the results* (this are all aimed at achieving the review metrics **C1 - C8** as listed earlier in the previous section)
4. The cut-off point was papers not earlier than 2005 in order to identify the current trends in this topic area and investigation.

### ***Database of E-Journals, Documents, and Index***

The following are lists of the topmost and relevant databases the work have used to perform its preliminary search and analysis:

- EBSCO (gives access to a number of Bibliographic and full-text Databases)
- Academic Search Complete (Academic Research Database)
- Business Source Complete (Business Research Database)
- Education Research complete (Scholarly Journals)
- Dblp.org (Computer Science Bibliography and Advanced Tech Database)
- ieeexplore.ieee.org (wealth of IEEE and IET transactions, Books, Journals, Conference proceedings and Standards.)
- ACM digital library (contains the full text of all 21 ACM journals and magazines)
- MEDLINE (Academic and Public Sector Medical Research)
- PsycINFO (Psychology)
- CINAHL Plus (Healthcare)
- ScienceDirect (Social Science and General Science Database)
- Emerald Insight (Business and academic Database)
- Compendex (Elsevier Engineering Index)
- Google Scholar
- Scopus
- Web of Science
- Web of Science Citation Index Expanded (SCIE)

### ***Search Terms***

In this section, the work presents the initial search terms it used to retrieve (search query) the papers from the different databases and/or sources, as follows:

**TITTLE-ABS-KEY** (Personal\* OR Adapt\* OR Learn\* OR Model\* OR Adapt\* System\* OR Personal\* System OR Learn\* Model\*)

**AND**

(Benefit\* OR Oppurtunit\* OR Impact\* OR Manage\* OR Weak\* OR Challeng\*)

**AND**

(Disabilit\* OR Disab\* OR Educat\* OR Health\* OR Learning\* OR ADHD)

**AND**

(Process\* OR Mining\* OR Modelli\* OR Discover\* OR Event\* OR Logs\* OR Activit\* Recognition)

### ***Refining the Search Terms***

The following table (Table 1) describes the search method the work have applied in order to narrow down the search terms to identify the best suitable and relevant paper for the purpose of the systematic review.

Whereas, Table 2 is a list of the found relevant studies with the preliminary analysis criteria and/or assessment properties (i.e. search to address the review metrics **C1** to **C8** based on the York method)

**Table 1. Results of the Search Terms and Papers Threads**

Scope	Search Term	Thread
Search to reveal papers associated with personalised adaptive learning and key research concept	TITTLE-ABS-KEY (Personal* OR Adapt* OR Learn* OR Model* OR Adapt* System* OR Personal* System OR Learn* Model*) AND TITTLE-ABS-KEY (Benefit* OR Oppurtunit* OR Impact* OR Manage* OR Weak* OR challeng*)	20, 000 + papers
Further, expound search to reveal all threads related to the keywords	TITTLE-ABS-KEY (Personal* OR Adapt* OR Learn* OR Model* OR Adapt* System* OR Personal* System OR Learn* Model*) OR TITTLE-ABS-KEY (Benefit* OR Oppurtunit* OR Impact* OR Manage* OR Weak* OR challeng*) AND TITTLE-ABS-KEY (Disabilit* OR Disab* OR Educat* OR Health* OR Learning* OR ADHD) AND TITTLE-ABS-KEY (Process* OR Mining* OR Modelli* OR Discover* OR Event* OR Logs* OR Activit* Recognition)	580 papers
Remove non-relevant (non-applicable) threads	TITTLE-ABS-KEY (Personal* OR Adapt* OR Learn* OR Model* OR Adapt* System* OR Personal* System OR Learn* Model*) OR TITTLE-ABS-KEY (Benefit* OR Oppurtunit* OR Impact* OR Manage* OR Weak* OR challeng*) AND TITTLE-ABS-KEY (Disabilit* OR Disab* OR Educat* OR Health* OR Learning* OR ADHD) AND TITTLE-ABS-KEY (Process* OR Mining* OR Modelli* OR Discover* OR Event* OR Logs* OR Activit* Recognition) AND NOT TITTLE-ABS-KEY (Physical Disab* OR Care* OR Medic*)	300 papers

**Table 2. Topmost papers discovered from the preliminary analysis criteria and review metrics/assessment**

Study target & Review Metrics	Place of study	Field of study relevant to E-learning?	Field	Aims relevant to Personalisation/Adaptation?	Finding(s) relevant to adaptive learning?	Design appropriate for research purpose?	If yes, then what Design approach was used?	Is method of inquiry evidenced and/or structured?	Evaluation of design and approach	Is the Framework adaptable for the research purpose?	Any ethical issue?
Review Metrics	-	C1	C1	C1, C2	C2, C3	C1	C3, C4, C5	C6	C6, C7	C8	C8
Nganji, J.T. et al, (2011)	UK, University of Hull	Yes	Personalisation of e-learning	yes	Yes, achieved using Semantic Web technologies such as ontologies	Yes	Ontology, Abilities and Disabilities Ontology for Online Learning and Services (ADGOLES) and OWL were used.	yes	Random testing	yes	Yes, heuristically tested on disabled experts
Huang, S.L., & Shiu, J.H. (2012).	Taiwan, National Taipei University	yes	Adaptive e-learning	yes	Yes, a user-centric adaptive learning system (UALS)	yes	uses sequential pattern mining and employed Items Response Theory (IRT)	unclear	Used collaborative voting approach to estimate learners' abilities	yes	n/a
Van Velsen, L.S. et al (2008)	Netherlands, printed in UK	Unclear	Adaptable systems	Yes, adaptive systems	Focuses on an adaptive system with no emphasis on learning	Yes,	The article models the iterative design process for adaptive and adaptable systems	Iterative, summarizes the variables to be assessed at each stage of the process and the relevant methods to assess them	Before and after	Unclear, The reports encountered do not fully support empirical value	n/a
Fröschl, C. (2005)	Austria, Graz University of Technology	yes	User Modelling and User Profiling in	yes	Yes, personalisation solution for the research project AdeLE	yes	Proposed solution approach for the implementation of a user	Evidenced	Existing user modelling systems were examined under the aspects	yes	n/a
Svjetlana, C. (2011)	USA, National-Louis University	yes	Adaptive E-learning Systems Web usability and e-learning	yes	(Adaptive e-Learning with Eye-Tracking) Yes, experimentally examined information problem solving on the web for students with Learning Difficulty in reading	yes	model based on a service-oriented architecture Experimental pretest-posttest control group study, with a repeated measures design, and a repeated measures ANOVA analysis. Hence, repeated variance (ANOVA) and pair-wise comparisons (with Bonferroni adjustment) were used to analyse data.	yes	Experimental findings. Experimental, participants were randomly assigned to the treatment and control groups.	yes	n/a
Lacava, P.G. (2007)	USA, University of Kansas and UK, Autism Research Centre, University of Cambridge.	yes	Assistive technology for learning	unclear	Yes, the study explored the use of assistive technology to teach emotion recognition (ER) in autistic students.	yes	Accessed emotional concept from facial and speech expression using The Cambridge Mindreading Face-Voice Battery for Children (CAM-C; Golan & Baron-Cohen, 2006) and tested participants ability to recognise emotions using The Child Feature-Based Auditory Task (C-FAT; Golan, 2006) and The Reading the Mind in Films Test-Children's Version (RMF-C; Golan, Baron-Cohen, & Golan, 2006)	Yes, but used a smaller sample size and the exclusion of an ASC or a typically developing control group, which might impair the validity of the research	Non-equivalent experimental group design. ER testing was conducted using a computer at pre- and post-intervention.	unclear	n/a
Pushpa, M. (2012)	India, Pondicherry University	yes	Adaptation in Learning Management systems(LMS)	yes	Yes, Meta-heuristic which was used in the intelligent tutoring system to provide a learning path in an adaptive way and a Learning Path Graph which describes the structure of domain knowledge and the	unclear	Ant Colony Optimization (ACO) although the author mentioned several approaches which were not comprehensively described.	unclear	Heuristic	unclear	n/a

					associated learning goals.							
<b>Insorn, P. &amp; Sanrach, C. (2012)</b>	Thailand, King Mongkut's University of Technology	yes	problem-based learning	Yes, Adaptive coaching system	presented a method for the Adaptive Coaching System	yes	synthesized a logical thinking approach for the computer student using EDRF technique	yes	Expert review	Yes, A conceptual framework was developed	n/a	
<b>Graf, S. et al (2010)</b>	Canada, Athabasca University	yes	Dynamic student modelling of learning styles in learning.	Yes, Adaptivity and Personalisation	Yes, proposed architecture which can be easily integrated in different learning systems to locate data about students' behaviour	Yes	Introduced an architecture for dynamic student modelling of learning styles based on the Felder-Silverman learning style model(FLSLM) (Felder and Silverman, 1988)	unclear	Generic. The architecture is developed in a generic way so that it can be integrated into different learning systems.	unclear	n/a	
<b>Le, D.C. et al (2010)</b>	Vietnam, HCM City	yes	Adaptive e-learning systems	yes	Yes, some illustrated examples were concretely presented to clarify advantage of learner profile in the system.	yes	generic user model developed using the rule-based induction, $\alpha$ -community spaces model and Expert-based knowledge	Inductive, based on the $\alpha$ -Community Spaces Model. Including components such as information about demographics, training experiences, self-study activities, learning demands	psychological and pedagogical foundations	yes	n/a	
<b>Niu, W.T. &amp; Kay, J. (2009)</b>	Australia, The University of Sydney.	yes	User modelling and user adaptation	Yes, personalised ontological reasoning in pervasive computing	Yes, evidenced Adaptive Locator which was built based on the PERSONAF (personalised pervasive scrutable ontological framework) Framework.	yes	The PERSONAF framework's three layer PECO ontology and the separate ONCOR reasoned used to provide a powerful, flexible means to support ontological reasoning for pervasive computing	yes	Empirical evaluations.	yes	n/a	
<b>Yarandi, M. et al (2012)</b>	UK, University of East London	Yes	Personalised learning, e-learning, Ontology, adaptive learning, Semantic web	Yes	Yes, presented a personalised e-learning system which creates adaptive content for learner based on learner's ability, learning style, level of knowledge and preferences.	Yes	An innovative Ontology-based approach and sequencing logic was used to design learner, content and domain model.	Yes, The content model described the structure of courses and their component.	Regular test during the learning process is analysed by the item response theory and the ability of learner is evaluated.	Yes	n/a	
<b>Conati, C. &amp; Maclaren, H. (2009)</b>	Columbia, University of British Columbia	Yes	User modelling/ User Adaptation	Yes.	Yes, presented a probabilistic model of user effect designed to allow an intelligent agent to recognise multiple user emotions during the interaction with an educational computer game	Yes	An OCC model based on a probabilistic framework that deals with the high level of uncertainty involved in recognising a variety of user emotions by combining in a Dynamic Bayesian Network information on both the causes and effects of emotional reactions.	Yes, empirical studies that adapt the theories to the target application domain	Illustrative. Complemented the model with diagnostic information.	Yes	n/a	
<b>Meo, P.D. et al (2010)</b>	Italy, Università Mediterranea di Reggio	Unclear, recommender system	User profiling	Yes	Unclear, Paper proposed a query expansion and user profile enrichment approach to improve the performance of recommender systems operating on a folksonomy	Yes	Presented the Borda Count technique to merge the lists of candidate tags into a unique list represented by two Ontological approaches: <i>Tag Resource Graph (TRG)</i> and <i>Tag User Graph (TUG)</i> .	qualitative and subjective tags evaluated using a built prototype in Java and MySQL	user queries and user profiles to allow any content-based recommender system to retrieve and suggest resources matching with user needs and desires	Yes	n/a	
<b>Despotović-Zrakić, M. et al (2012)</b>	Serbia, University of Belgrade	Yes.	Learning management systems (LMS)	Yes	Yes, enhanced an existing E-learning system.(Moodle LMS) by developing a method for creating adaptive courses	Yes	Described method using data mining techniques to classify students into clusters with regards to Felder-Silverman learning styles model.	unclear	Statistical analysis of the gathered data and the experimental group.	Unclear, validity is questioned? small sample size, a time limit (only One semester for the course) and not having enough data about students	n/a	

Mancera, L. et al (2011)	Spain, University of Girona	Yes	Attention Deficit Hyperactivity Disorder, Adaptive Hypertext System, LMS, User Modelling	Yes	Yes, paper presented an approach to adapt a playful space and an organizational space in LMS which automatically adapts according to each student's ADHD symptomatic profile inferred by a user modeling approach	Yes	The communication between the external evaluation tools and the LMS was achieved through the implementation of an interface using the XML-RPC protocol, the short version of the adult ADHD Self-Report Scale (ASRS v1.1) and the Sustained Attention Task (SAT).	Yes	LMS-LD specification and implementation of external evaluation tools	Yes	n/a
Okoye, K. et al, 2014	UK, University of East London	Yes	Accessibility of dynamic web pages and contents	Yes	Yes, proposed a hybrid method (agile + no-frills) for e-content access on the web	Yes	designed a framework that is structurally flexible, by removing unnecessary extras and thereby making every bit useful (fit-for-purpose)	Yes	Experimental evaluation of both online and face-to-face participants/surveys	Yes	Yes, visually impaired participants
Okoye, K. et al, 2018	UK, University of East London	Yes	Application of a process mining (PM) framework to manage information values of a Learning process domain	Yes	Yes, provides a method that allows for mining and improved analysis of the learning process models through semantic labelling, representation, and reasoning.	Yes	presents a semantic-based process mining framework (SPM <sub>AF</sub> ) that makes use of labels within events logs to discover useful and semantically enhanced process models	Yes	Uses a combination of both the qualitative and quantitative method of evaluation to validate the approach	Yes	n/a
Nganji, J.T. et al (2013)	UK, University of Hull	Yes	E-learning Personalisation and Ontology	Yes	Yes, Automated ontology-based agents intercommunicating that provides effective personalisation for disabled students as well as ONTODAPS that is flexible enough to provide control and freedom to drive their learning.	Yes	presented personalisation and its techniques and then presents ONTODAPS, which personalises learning resources and services to students	Yes	Inclusion of multiple formats of learning resources and personalisation of their presentation to students	Yes	n/a

## SYSTEMATIC ANALYSIS OF THE REVIEW RESULTS AND OUTCOMES

At first, the review search method produced a very large number of documents and research papers.

- i The relevant documents/papers were noted.
- ii Duplicates of papers were identified and removed, and
- iii The abstract of the remaining results was read and recorded.

Accordingly, the listed criteria in the methodology section of this paper were applied to the abstracts which resulted in fewer studies of which the full text were read and recorded. Notably, a greater number of those papers (i.e. the majority of the studies) turn out not to meet the criteria for selection which were subsequently excluded for the analysis purposes. The remaining relevant studies were then systematically reviewed, and the papers were reported as shown in the Matrix Table (Table 3) and also listed in the references/bibliography section.

Interestingly, a number of the studies focused on the evaluation of individually built system (of which some of the papers describe a series of logical sequence

evaluation, process mining and modelling methods as well as events log formats and case studies). Although, for the general rule of thumb, the scale of preference for most of the evaluated systems were learning systems, followed by user-centric evaluation of the adaptive and adaptable system, and then process mining and/or modelling. Other areas the review also encountered frequently was the user modelling and user profiling methods and approaches.

Thus, the following Table 3 is a thematic representation of the review analysis results and outcomes for the most relevant and appropriate papers based on the selection criteria listed in the methodology section and for the purpose of addressing the review investigation metrics (C1 – C8).

**Table 3. Thematic representation of the review analysis and results for the most relevant and appropriate papers based on the review criteria (C1-C8)**

Paper	Domain (C1)	Scope of Study (C1, C2)	Approach (C4, C5)	Tools (C3)	Scientific contribution (C6 – C8)	Result (C6 – C8)
Mancera, L. et al (2011)	Learning Management System (LMS), Attention Deficit Hyperactivity Disorder (ADHD)	(1)Adaptive Hypermedia Systems and User Modelling. (2)Adapt a playful space and an organisational space in LMS to support virtual learning in adults with ADHD	(1) A user Modelling approach to infer ADHD students symptomatic profile (2) use of playful spaces: attempt to train cognitive deficiency in people with ADHD. and (3) provision of a strategy to motivate them. Also, an organisational space that attempts to facilitate students works by presenting organized folders to remind them of the status of their task.	Set of Classification Rules: used as variables in different Contexts through the use of - Behavioural Management test - Cognitive Performance task/test - Emotional Recognition exercise -Emotional Regulation system	The proposed User model provides the Information to adapt the workspace of students with attention problems such as ADHD	The project resulted in offering a generalized user model that considers cognitive and emotional dysfunctions. Hence the authors saw it as an opportunity to expand the range of users to which the development can be addressed. The Platform also allowed integration with several LMSs through game exportation following educational standards, particularly the IMS-LD specification (a model containing specific information about each learner)
Tiwari A. et al (2008)	Business Process Mining	Overview of the state of the art techniques in a business process mining	The paper was based on a comprehensive review of the literature covering more than 50 research papers. These papers were analysed to identify the current trends and future research directions in the business process mining field.	Flow diagram representations of process and mining heuristics	An application of soft computing techniques to process-mining problems. Which is applicable to learning process mining	The review concludes that Process-mining techniques are now becoming available as graphical interface-driven software tools, where flow diagram representations of processes may be manipulated as part of the mining task
Tong M.W. et al (2010)	Service Content, Ontology, Content adaptation, and E-learning	The Authors described key points in Content adaptation technology by identifying four factors that determine Rules in service context in relation to object property. And then proposed a novel context model on the	The authors used the reasoning ability of ontology to find some information and decrease the data size of service context that holds the ability to coding rules. The implementation and performance evaluation of	Ontology Modelling and Protégé through an inferring platform was used to construct service contents to prove the feasibility of the model based on four factors; User,	Service content Adaptation was proposed by MPEG-21 to solve the problem of mismatch between multimedia content and Service context.	Overcomes the shortcomings of the existing models. But the context model is not comparable with the existed models and the operation on the model is not able to be logged, which the authors suggested should be improved in future research



		basis of ontology that has the capability to reason and describe	the context model was also presented	Device, Network and Natural circumstances. The Usage Environment Description (UED) was used to provide a hint about the Metadata adaptation based on two ways of user preferences. >MPref (modality preferences) >Eypref (format preferences) And Web Agents to record the capabilities		
<b>Ferreira &amp; Thom (2012)</b>	Workflow Activity Patterns (WAPS), Event Logs	Adapting semantic Reasoning to solve the problem of determining the presence of workflow activity patterns in a purchase process model.	Adapted semantic reasoning and process model to discover WAPS in event logs through > Approval > Question-Answer >Unidirectional performative > Bidirectional performative > Notification > Information request > Decision	> Ontology > Semantic annotation of Event Logs > Protégé > Pellet Reasoner plug-in > Java Code > Jena framework	> Defined the elements that each pattern contains which can be generated automatically from an event log recorded during process execution. > Provides an automated means to assist the designer in the discovery of WAPS.	The research resulted in the provision of a Purchase process implemented in a commercial Workflow system.
<b>Chen L. &amp; Nugent (2009)</b>	Activity Recognition, Pervasive Environments.	Aiming to consolidate and improve existing API approaches in terms of scalability, applicability, and ease-of-use	Introduces the concept of a domain knowledge-driven approach to activity recognition. The approach adopts ontological modeling as the conceptual backbone covering the lifecycle of activity recognition in a sensorized pervasive environment	Data mining and machine learning techniques through probabilistic and statistical reasoning. These include Hidden Markov Models (HMMs) (Patterson, 2005; Ward, 2006; Boger, 2005), dynamic and naive Bayes	course-grained ADL recognition (class and subclasses) and Fine-grained activity recognition (personalised) was carried out using the latest Protégé toolsets making full use of the reasoning power of semantic modelling and representation	The authors argue that currently there are two types of activity recognition: vision-based activity recognition and sensor-based activity recognition.
				networks (Philpote, 2004; Wang, 2007, Albrecht, 1998), decision trees (Tapia, 2007), nearest neighbour (Lee, 2002) and support vector machines (SVMs) (Huynh, 2007), graphical models (Liao, 2007) and multiple eigenspaces (Huynh, 2006)		
<b>Verbert K. et al (2007)</b>	Technology Enhanced Learning (TEL), Recommender System, Adaptive and Intelligent Educational Systems, Personalised E-Learning, System Applications, and Experience	The paper assessed the extent to which current work (state-of-the-art) in TEL Recommender system through contextualization is researched, and utilized the outcome as a paradigm for building intelligent systems that can better predict and anticipate the needs of users and act more efficiently in response to their behaviour.	The researchers conducted a survey of Context-aware recommender systems that have been deployed in TEL settings.	The authors implemented the approach through Review of existing Literature and System Survey.	The paper presented a context framework for a contextual recommendation in TEL that identifies relevant context dimensions for TEL applications. > The framework can be used to drive an in-depth analysis of context-aware TEL recommenders. > Finally, based on an analysis of existing context-aware recommender systems, the work outlined directions of future research in this area.	Results of the survey indicate that there has been much advancement in the development of context-aware TEL recommenders in recent years. It shows that there are many promising prototypes that illustrate the potential and opportunities that these systems create. It also revealed the important challenges related to the capturing and use of contextual data remain that need to be tackled in order to increase uptake and validate research efforts in realistic trial experiments.
<b>Hong X. &amp; Nugent C. (2010)</b>	Activity Recognition	demonstrated the process of generalising evidential ontology network models under instances of real sensor installations and present the results following the evaluation of our models based on the dataset collected	The paper used rudimentary domain knowledge to extract the relation hierarchy of an activity with object interactions and automatically convert this into the formal model.	Decision trees	Proposed an <i>evidential ontology network</i> (EON) model of activity recognition based on sensor evidence.	Presents the details of the creation of the evidential ontology networks for the different activities to be recognized within the data set along with the necessary decision rules.

## DISCUSSIONS

The systematic review carried out in this paper shows that a lot of work has been done in the areas of developing personalised adaptive learning system (C1, C5).

However, on the other hand, very little has been done to effectively use such system to enhance the learning process of users (e.g. the learners, or with ADHD) (Hidalgo, et al, 2011) (C6, C7). The research aims to help validate and clarify this flaw in literature. To this end, significant findings within the available literature were discussed and reviewed - which includes especially:

- ✓ An overview of the state-of-the-art contribution by Tiwari et al (2008). The authors mention that process mining and modelling techniques are now becoming available as graphical interface-driven software tools: where the flow diagram representations of processes may be manipulated as part of the mining task to help in interpretation and understanding of the processes in reality (C2, C3, C4).
- ✓ A significant number of the reviewed papers also employs the process modelling and/or heuristics method to aid in the task of process mining and discovery. (Tong et al, 2010; Ferreira & Thom, 2012; Chen & Nugent, 2009) (C4, C5).
- ✓ Interestingly, soft computing algorithms are increasingly being investigated to support the accuracy and speed of the process mining and/or modelling methods. Likewise, many papers exist that addresses some common problems with the process mining and analysis techniques (Li, et al., 2010; Homayounfar, 2012, Mărușter & Beest, 2009; Pedrinaci & Domingue, 2007; Okoye et al, 2018) (C5, C8).

On one hand, whereby problems such as duplicate tasks, mining perspectives, and delta (or metadata) analysis require further research (Tiwari et al, 2008) (C7). On the other hand, another significant finding from the review shows that current innovations may be what motivates software engineers over the prominence to provide personalised adaptive learning systems (C7, C8). Besides, with such system, which are also referred to as *intelligent systems* (Okoye et al, 2018) - learners can proceed at their own pace, get recommendations about what learning content best fits their needs, practice as much as they need on their own, and move ahead to greater challenges when motivated by interest or data that demonstrates they have mastered a skill (Brindley, 2004). Furthermore, blended classrooms that utilize both the personalised contents and project-based learning activities are already in use in pilot programs - like the School of One in New York (School of One, 2012) (C3, C4), in field tests, in experimental private schools, and in public or online classrooms, but little has been done to assist learners with additional learning requirements such as the ADHD (C7). Moreover, at the higher education level, the Open Learning Initiative (OLI) (2006) at Carnegie Mellon University is

conducting powerful research into the design of effective personalised adaptive learning systems (C1, C2, C8).

In fact, an important pragmatic concern is that it must be inexpensive to create the contents or representations for the adaptive learning systems, particularly the new users of the system (Niu & Kay, 2010) (C6). It also should dynamically update the representation to take into account the changing state of the users and the changes in the information that is relevant to each of the users over time (C6, C7, C8). Perhaps, with such method (i.e. adaptive learning system), the system is envisaged to be applicable especially for learners (e.g. with ADHD) to manage their learning process and also help improve their lives and activities of daily life thereby bridging the gap between such learners and the other learners that requires lesser content adaptation or personalisation (C7, C8).

In general, this systematic review has shown - how the personalisation, as well as effective utilization of the process mining and modelling methods, can be used to manage and improve the learning process with the users (e.g. learners) in mind. The study notes that such systems should take into account the users profile which includes - the users background, learning styles and goals. Clearly, the focus is not just to develop a dynamic e-learning system that supports and allows for different adaptive mechanisms, learning paths, and/or contents that fit the learner's diverse needs and background, but also by considering the fact that there is an additional task of matching those persons (user profiling) with solutions that best fit their particular learning needs (personalisation). Moreover, the platform should enable users to create, share and collaboratively edit contents to suit their individual learning needs (Dietze et al, 2009). In short, the implication and impact of this review evolved to be more of a narrowing down from advocating or supporting the creation of *assistive technologies for learning* for the users (e.g. learners) to improving and *making effective the learning process* in general.

## CONCLUSION

Evidently, from the systematic review and findings of this paper, it is shown that one of the key challenges in developing a personalised adaptive system for learning - is to build an effectively represented *user's profiles, learning styles, and patterns/behaviour* to help support reasoning about each learner. Technically, the design and implementation of such a system need to be able to describe and support metadata (semantic) interpretation about the learners and provide effective ways to adapt the information about each user and/or profiles. On the whole, the proposed method of analysis is envisaged as a novel approach towards the creation of systems that are capable of adapting to each user profile (e.g. during the learning process)

in order to suggest, and better still, recommend the right content for each learner in line with their learning style rather than just the physical and/or cognitive capacity. Future works will focus on analysing the existing process mining algorithms and their application in real-time using different case studies.

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