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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-contents 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 knowledgeablely 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 predefined 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:
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:

- 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:


**TITLE-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>
<thead>
<tr>
<th>Scope</th>
<th>Search Term</th>
<th>Thread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search to reveal papers associated with personalized adaptive learning and key research concept</td>
<td>TITITLE-ABS-KEY (Personal* OR Adapt* OR Learn* OR Model* OR Adapt* System* OR Personal* System OR Learn* Model*) AND TITITLE-ABS-KEY (Benefit* OR Oppurtunit* OR Impact* OR Manage* OR Weak* OR Challeng*)</td>
<td>20,000 + papers</td>
</tr>
<tr>
<td>Further, expound search to reveal all threads related to the keywords</td>
<td>TITITLE-ABS-KEY (Personal* OR Adapt* OR Learn* OR Model* OR Adapt* System* OR Personal* System OR Learn* Model*) OR TITITLE-ABS-KEY (Benefit* OR Oppurtunit* OR Impact* OR Manage* OR Weak* OR Challeng*) AND TITITLE-ABS-KEY (Disabilit* OR Disab* OR Educat* OR Health* OR Learning* OR ADHD) AND TITITLE-ABS-KEY (Process* OR Mining* OR Modelli* OR Discover* OR Event* OR Logs* OR Activit* Recognition)</td>
<td>580 papers</td>
</tr>
<tr>
<td>Remove non-relevant (non-applicable) threads</td>
<td>TITITLE-ABS-KEY (Personal* OR Adapt* OR Learn* OR Model* OR Adapt* System* OR Personal* System OR Learn* Model*) OR TITITLE-ABS-KEY (Benefit* OR Oppurtunit* OR Impact* OR Manage* OR Weak* OR Challeng*) AND TITITLE-ABS-KEY (Disabilit* OR Disab* OR Educat* OR Health* OR Learning* OR ADHD) AND TITITLE-ABS-KEY (Process* OR Mining* OR Modelli* OR Discover* OR Event* OR Logs* OR Activit* Recognition) AND NOT TITITLE-ABS-KEY (Physical Disab* OR Care* OR Medic*)</td>
<td>300 papers</td>
</tr>
</tbody>
</table>
Table 2. Topmost papers discovered from the preliminary analysis criteria and review metrics/assessment

<p>| Study &amp; Target Review Metrics | Place of study | Field of study relevant to E-learning? | Field | Tools relevant to Personalisation/Adaptation? | Finding(s) relevant to adaptive learning? | Design appropriate for research purposes? | If yes, then what design approach was used? | Is method of inquiry evidenced and under structure? | Evaluation of design and approach | Is the framework of adaptability fit for the research purpose? | Any ethical issue? |
|-------------------------------|----------------|-------------------------------------|--------|---------------------------------------------|---------------------------------------------|------------------------------------------|-----------------------------------------------|--------------------------------|---------------------------------------------|--------------------------------|----------------|----------------|
| Ngaushi, J.T. et al. (2011)   | UK, University of Hull | Yes | Personalisation of e-learning? | Yes | Yes, achieved using Learntotic. Flash technology such as animations | Yes | On-line: abilities and disabilities; On-line for Online learning and Systems (AODUOS) were used. | Yes | Random testing | Yes | Yes, humanly tested on disabled experts |
| Huang, S.L., &amp; Shin, J.H. (2012) | Taiwan, National Taipei University | Yes | Adaptive e-learning | Yes | Yes, a user-centric adaptive learning system (UALS) | Yes | User experience; grouping and employed based on Response Theory (RT) | Nuclear | Used collaborative voting approach to prioritize learners’ abilities | Yes | n/a |
| Vossoughi, L.S. et al. (2008) | Netherlands, joined as UK | Yes | Adaptive 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 | Yes | Assumptions; the variables to be assessed at each stage of the process and relevant methods to ascertain them | Before and after | Nuclear; The reports encountered do not fully support empirical value | n/a |
| Ynsochi, C. (2009) | Austria, Graf University of Technology | Yes | User Modelling and User Profiling | Yes | Yes, personalisation solution for the research project AbLE | Yes | Proposed solution approach for the implementation of a user model | Evaluated | Learning user modelling systems were examined under the aspects | Yes | n/a |
| Vygodtsev, D. (2011) | USA, National-Louis University | Yes | Web usability and e-learning | Yes | Yes | Experientially examined information; problem-solving; test with five students with Learning Difficulty in reading | Yes | Experiential permute-contextual group study; with a repeated measures design and a repeated measures ANOVA (3x2) and pair-wise comparisons (Bonferroni adjustment) were used to analyse data | Yes | Experiment; participants were randomly assigned to the treatment and control groups | Yes | n/a |
| Lacava, P.G. (2007) | USA, University of Kansas and UK, Action Research Centre, University of Cambridge | Yes | Assistive technology for learning | Nuclear | Yes, the study explored the use of assistive technology to teach expressive recognition in autism; students. | Yes | Accidental datasets from facial and speech expressions using The Cambridge Adaptable Face-Force Sensory for Children (CAM-C-FFS) by64 &amp; Bevan Cullen, (2006) and were used to recognize emotions using The Visual Feedback-Based auditory task (C-FAT) by Cullen, (2006) and The Reading the Mind In Eyes Children’s FISIP (RM-C-FCOE, Barresi, Cullen, &amp; Gallo, 2006). | Yes, yes and a smaller sample size and few inclusion of an ASC in a typical developing group which might impact the validity of the research | Non-equivalent experimental group design; ER testing was conducted using a computer at pre- and post-intervention | Nuclear | n/a |
| Fuchun, M. (2013) | China, Peking University | Yes | Adaptive learning management system (ALMMS) | Yes | Yes | Mobile-learning; the mobile learning system was implemented to provide a learning path in an adaptive way and a Learning Path Report which describes the student’s knowledge and for | Nuclear | All Classroom Opportunities (ACO) although the initial motivation several approaches which were not comprehensively described | Nuclear | Necesary | Nuclear | n/a |</p>
<table>
<thead>
<tr>
<th>Insom, P. &amp; Sarrach, C. (2012)</th>
<th>Thanh, Dang</th>
<th>yes</th>
<th>problem-based learning</th>
<th>Yes</th>
<th>Adaptive learning system</th>
<th>Yes</th>
<th>Synthesized a logical thinking approach for the computer student using EDRED technique</th>
<th>yes</th>
<th>Expert review</th>
<th>Yes</th>
<th>A conceptual framework was developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid, S. et al (2010)</td>
<td>Dynamic student modelling of learning styles in education</td>
<td>yes</td>
<td>Dynamic adaptive personas</td>
<td>Yes</td>
<td>Adaptive learning system</td>
<td>Yes</td>
<td>Explored an architecture which can be easily integrated into different learning systems to locate data about student's behaviors</td>
<td>yes</td>
<td>Informed, that the architecture is developed in a generic way so that it can be integrated into different learning systems</td>
<td>uncleat</td>
<td>0/5</td>
</tr>
<tr>
<td>Le, D.C. et al (2010)</td>
<td>Varian, HCM City</td>
<td>yes</td>
<td>Adaptive e-learning system</td>
<td>Yes</td>
<td>Yes</td>
<td>Sun Illuminated example was creatively presented to clarify advantage of learner profile in the system.</td>
<td>yes</td>
<td>generic user model developed using the rule-based induction, a committed expert model and Expert-Based Knowledge</td>
<td>Inductive, based on the Community Support Model, including components such as information about demographic, training objectives, self-study activities, learning resources</td>
<td>Psychological and pedagogical foundations</td>
<td>yes</td>
</tr>
<tr>
<td>Nin, W.T. &amp; Kay, J. (2009)</td>
<td>University of Sydney</td>
<td>yes</td>
<td>Use modelling and not adaptation</td>
<td>Yes</td>
<td>personalised and scenario-oriented system</td>
<td>Yes</td>
<td>Personalised Adaptive System which was built based on the PERSONA (personalised pervasive scenario-oriented) framework</td>
<td>yes</td>
<td>The PERSONA framework is based on the PECSO usability and the Personal UGC model, used to provide a powerful, flexible means to support the ontological reasoning for personal computing</td>
<td>yes</td>
<td>Empirical evaluations</td>
</tr>
<tr>
<td>Yarendi, M. et al (2012)</td>
<td>UK University of East London</td>
<td>Yes</td>
<td>Personalised learning, Adaptive Learning, Ontology-based learning, Semantic web</td>
<td>Yes</td>
<td>Yes</td>
<td>Personalised Adaptive System which was built based on the PECSO usability and the Personal UGC model, used to provide a powerful, flexible means to support the ontological reasoning for personal computing</td>
<td>Yes</td>
<td>An inductive Ontology-based approach and sequencing logic was used to design learners, contents and a test model</td>
<td>Yes</td>
<td>The content model described the structure of course and the four components</td>
<td>Regular test during the learning process is assessed for a linear sequence theory and the ability of learner is evaluated</td>
</tr>
<tr>
<td>Conati, C. &amp; Maclaren, H. (2000)</td>
<td>Columbia University</td>
<td>Yes</td>
<td>User Modelling/Adaptive User Adaptation</td>
<td>Yes</td>
<td>Yes</td>
<td>An OCC model based on an adaptive framework that deals with the high level of uncertainty involved in generating a variety of user mentions by combining in a Dynamic Bayesian Network, information in both the scenario and parameters of mentioned mention</td>
<td>Yes</td>
<td>Empirical studies that adapt the model to the target applications domain</td>
<td>yes</td>
<td>Diagnostic Compliant for model with diagnostic information</td>
<td>Yes</td>
</tr>
<tr>
<td>Mos, P.D. et al (2010)</td>
<td>Italy: University of Modena &amp; Reggio Emilia</td>
<td>User profile</td>
<td>Yes</td>
<td>User profiling</td>
<td>Yes</td>
<td>Unclear: Paper proposed a query expansion and user profile enhancement approach to improve the performance of recommendation systems operating on a follow-up</td>
<td>Yes</td>
<td>Unclear: Paper proposed a query expansion and user profile enhancement approach</td>
<td>yes</td>
<td>any context-based recommendation systems to retrieve and suggest resources matching user needs and desires</td>
<td>yes</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>Paper</th>
<th>Domain (C1)</th>
<th>Scope of Study (C1, C2)</th>
<th>Approach (C4, C5)</th>
<th>Tools (C3)</th>
<th>Scientific contribution (C6 - C8)</th>
<th>Result (C5 - C8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mancera, L. et al (2014)</td>
<td>Learning Management Systems (LMS), Attention Deficit Hyperactivity Disorder (ADHD)</td>
<td>Adaptive Hypermedia Systems and User Modelling. 2. Use a playful scale and an organisational scale to support virtual learning in adults with ADHD</td>
<td>1. A user Modelling approach to define ADHD students' symptomatic profile 2. Use of playful spaces to test cognitive deficiencies in people with ADHD, and 3. provision of a strategy to motivate them. Also, an organisational space that attempts to facilitate student work by presenting organized folders to remind them of the vims of their task</td>
<td>Set of Classification Rules; used as variables as different countries through the use of: Behavioural Management test; Cognitive Performance task/test; Emotional Recognition exercise; Emotional Regulation system</td>
<td>The proposed User model provides the information to adapt the workplace of students with attention problems such as ADHD</td>
<td>The project resulted in offering a personalized 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 representations following educational standards, particularly the IMS-LD specification (a model combining specific information about each learner)</td>
</tr>
<tr>
<td>Torello A. et al (2008)</td>
<td>Business Process Mining</td>
<td>Overview of the state of the art techniques in the business process mining</td>
<td>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.</td>
<td>Flow diagram representations of process and semantic features</td>
<td>An application of soft computing techniques to process mining problems, which is applicable to learning process mining</td>
<td>The review concludes that Process mining techniques are now becoming available as graphical interface-driven software tools, whose flow diagram representations of processes may be manipulated as part of the mining task</td>
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<tr>
<td>Tong M-W. et al (2010)</td>
<td>Service Content, Ontology, Context adaptation, and E-learning</td>
<td>The Authors described key ways in Context adaptation technology by identifying four factors that determine if the service content is relevant in relation to object property. And then proposed a novel content model on the</td>
<td>The authors used the remaining ability of ontology to find some information and decrease the data size of service context that builds the ability to coding rules. The implementation and performance evaluation of Ontology Modelling and Protégé through an informing platform was used to connect service context to prove the feasibility of the model on four factors. Use.</td>
<td>Service content Adaptation was proposed by MPEG-21 to solve the problem of mismatch between multimedia content and service context.</td>
<td>The authors overcomes the shortcomings of the existing models. For the context model is not comparable with the existing models and the operation on the model is not able to be logged, which the authors suggested should be improved in future research</td>
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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, Măruşter & 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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Process Modelling Methods and its Application for Personalised Adaptive Learning Systems

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