

Teaching of Clinical Workflow Analysis with Process Mining: An Experience Report

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Abstract

There is an increased demand of developing workforce in healthcare industry within USA. KSU offers a set of degrees and certificates in Health Information Technology. In this paper, we describe our experience of designing process mining based hands on workflow analysis learning module. We provide some examples of resources and assignments that were introduced for a graduate HIT course, followed by initial student's feedback. The course modules can be reused by other instructors to raise more awareness on tool-based improvement of healthcare delivery quality and cost reduction.

Keywords: Process mining, clinical workflow analysis, data mining redesign, disco, prom.

1. INTRODUCTION

There is a steep demand of developing workforce for USA health care industries. KSU offers a set of degree and certificates in Health Information Technology. Unfortunately, healthcare cost in USA is the highest among all developed nations in the world (Blumberg, 2018). According to a report (Allen & Pierce, 2016), more than 250,000 Americans die each year from medical errors. Medical error is the third major cause of patient's deaths in USA. Clinical workflow has gotten a lot of attention from the healthcare communities to address these issues.

Process Analysis is an examination of a process to understand its elements such as steps and actions, the relationships between them, order of steps, what could be done in parallel versus sequentially, who or what performs the steps, and what could be improved. Process analysis also looks for things like gaps, lack of conformity with

best practice, undue delays, redundancy, rework, and lack of efficiency.

According to Campbell, Gantt & Congdon (2009), there is a lack of effort on how to teach workflow analysis concepts the best way to students and practitioners in the healthcare industries (Campbell et al., 2009). Currently, we see very little effort in the literature focusing on innovative learning materials for classroom teaching of clinical workflow process analysis. For example, Coursera offers interprofessional healthcare informatics module, where workflow processes are introduced without engaging technologies (University of Minnesota, n.d.). Campbell et al. 2009, reported a video simulation software to teach lean thinking based workflow analysis technique to adopt Electronic Health Record applications. The approach may not live our expectation today, considering EHRs are already in place and more personal record being added every day by patients themselves, while health

data has grown huge in size requiring knowledge of data mining to handle.

In this paper, we describe our design of a new course module in a Health Information Technology (HIT) course at Kennesaw State University, known as on “Clinical Process and Workflow: Analysis and Redesign”. We provide some examples of resources and assignments introduced for a graduate class, followed by student’s reflection and feedback. The course modules can be reused by other instructors while the outcome is to increase more awareness of tools to improve the quality of healthcare and reduce the cost of services.

This paper is organized as follows. Section 2 provides an overview of process mining and the tools we use in our developed modules. Section 3 introduces the developed contents, assessment in details. Section 4 provides some initial feedback from classroom students. Finally, Section 5 concludes the paper.

2. PROCESS MINING TOOL

Process mining techniques allow the extraction of useful and nontrivial information from execution logs stored in information systems. There are three types of process mining techniques: discovery, conformance checking, and enhancement or extension. All these techniques allow us to analyze actual execution of processes. The discovery technique is used to extract process models from an event log. Conformance checking techniques are used to monitor deviations by comparing the model and the event log and improving existing models from its extension (Orellana García, Pérez Alfonso, & Larrea Armenteros, 2015). Healthcare processes (e.g., appointment scheduling, insurance claim processing) are highly dynamic and complex (Homayounfar, 2012). Healthcare processes improvement might have a high impact on the quality of life of patients. However, improving them is not an easy task and several challenges are always present. There is always the need to reduce the cost of services and improve capabilities to meet the demand, reduce patient’s waiting times, improve resources productivity, and increase processes transparency (Rojas, Munoz-Gama, Sepúlveda, & Capurro, 2016).

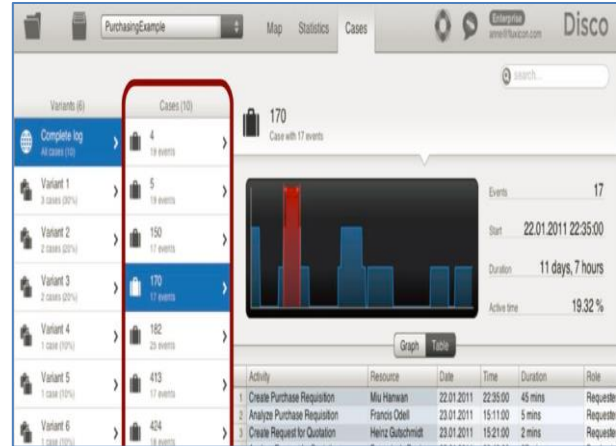


Figure 1: A screenshot of Disco tool

Figure 1 shows an example analysis of a process from CSV file data, whereas Figure 2 shows a screenshot of importing log data from files stored as CSV format.

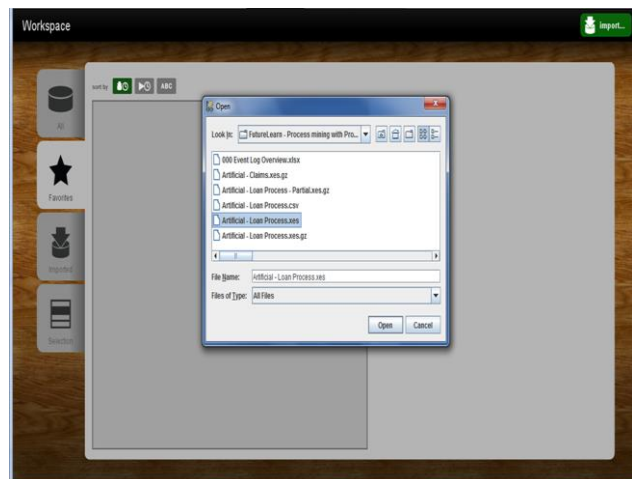


Figure 2: ProM tool screenshot

We used two open source tools for process mining named ProM (Process Mining Group, Eindhoven Technical University, 2018) and Disco (Fluxicon BV, 2018). Both tools allow a user to generate process maps (which are based on states and edges) and allow to analyze the process and identify bottleneck. Disco is for beginner learner and has simple interface, while ProM allows advanced mining using various algorithms to perform complex process map generation and analysis from event data. Figure 1 and Figure 2 show example screenshots of Disco and ProM tools, respectively.

3. MODULE CONTENTS

There are three units to support the contents and assignments. Unit 1 included a brief lecture on process mining overview and application to health care settings. An assignment was developed to critically examine literature article on process analysis techniques and improvement opportunities. The assessment connects process analysis with prior knowledge base on control flow, data flow, organizational and performance perspectives. The learners need to be able to identify specific application of process mining towards process discovery, conformance checking, and enhancement.

Unit	Content type	Assessment	Source
1	Reading materials	Writing assignment	(Bose, 2012; Ramos, 2009; Rebuge & Ferreira, 2012)
2	Disco introduction	Process map generation and analysis	(Process Mining Group, Eindhoven Technical University, 2018)
3	Prom introduction	Discussion among peers to compare mining tools	(Ramos, 2009)

Table 1: Module contents and assessment

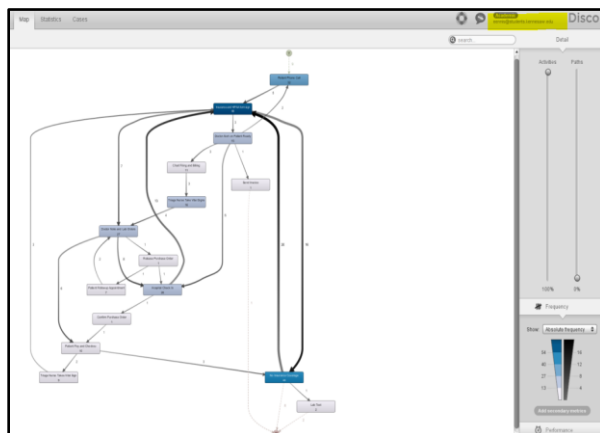


Figure 3: An example of visual process model in Disco

In Unit 2, an overview of Disco process mining tool and its application to process analysis was introduced. A sample of clinical dataset was developed in one of our earlier works for

classroom students (see ("IEEE SoutheastCon 2018," 2018) for details) to perform hands on analysis of workflow and bottleneck discovery. The input data file included timed events for activities such as patient arrival, patient departure, test order, and payment. The data was saved in a CSV file so Disco can import. The key task was to generate a visual process model.

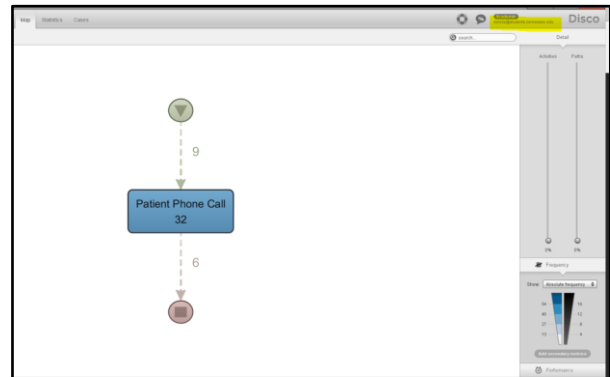


Figure 4: Highest occurring event example

Figure 3 shows an example of student work generating process diagram. Based on the diagram, some analysis were performed. For example, what activities occurred highest number of times (Figure 4); whether there are instances of process deviation including median and mean duration (Figure 5); identifying activities in the process took longer time (Figure 6).

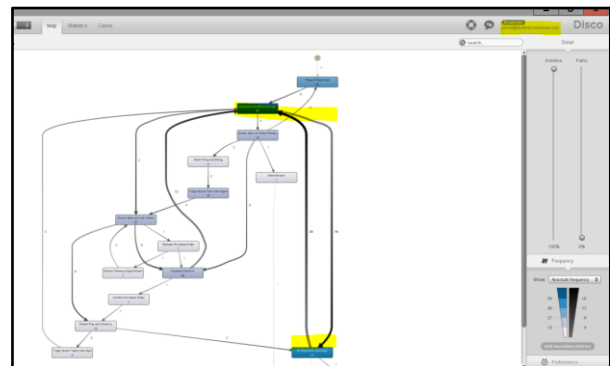


Figure 5: Example of process deviation (bold lines)

The events that took most of the time with resources and roles involved can enable bottleneck analysis. The analysis helps practitioners to reassign individuals to provide service faster and reduce delays among processes, or come up with parallel process for more efficiency. Learners are required to provide recommendation of improvement based on the analysis performed using Disco tool.

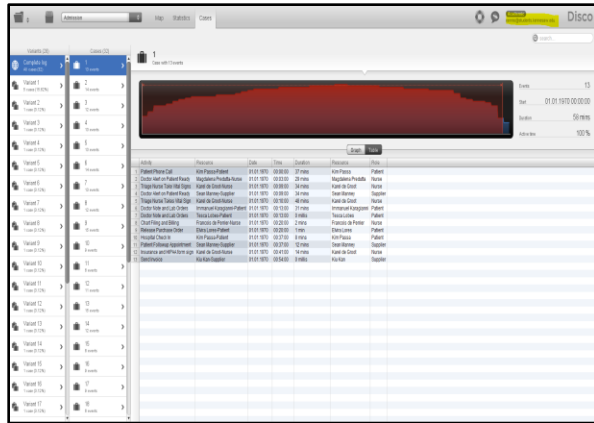


Figure 6: Examples of events taking longest times with involved resource and roles

Unit 3 introduces Prom tool. The ProM tool contains over thirty sets of algorithms that can be used to generate information from the data. Most of the common Algorithms are Alpha, Heuristic, Fuzzy and Inductive Miners. The Alpha Miner can be used to create Petri Nets (a place/transition (PT) net. This is one of several modeling languages for the description of a distributed system. It is a directed bipartite graph where the nodes represent transitions and places (represented by circles) and producing output.

The assessment in this unit included a discussion topic among students. A comparison of capability between Disco and ProM tools need to be done, followed by comparing various mining techniques, particularly when they should be applied for checking compliance with common process such as patient registration.

4. STUDENT FEEDBACK

We applied the developed learning module during Spring 2018 IT6523 course at Kennesaw State University (KSU). The students were from MS in Information Technology and MS in Health Management Informatics students. We performed a survey to assess the effectiveness of our learning materials.

There were total 2 questions to understand the background knowledge on workflow analysis and process mining (see Table 2, B1-B2). The response of the questions were recorded on a scale from 1 (one) to 5 (five), where one is beginner and five is advanced, the response was recorded using anonymous surveys. There were total 32 students, we received 15 responses.

Among 15, only 3 were expert in healthcare domains, the remaining 12 has little or no

exposure to clinical workflow process (see Figure 7 below).

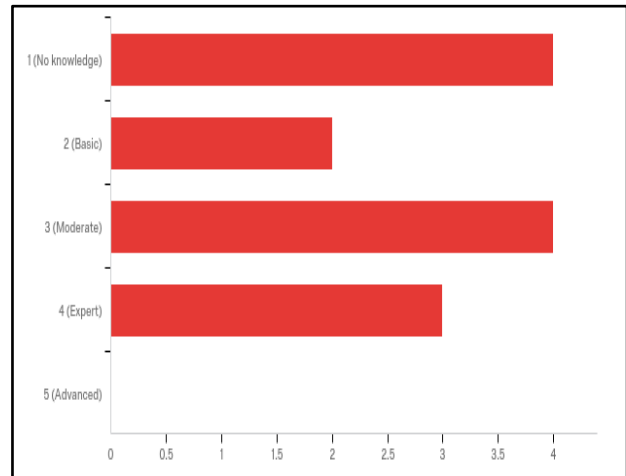


Figure 7: Survey response - characterizing knowledge and background on clinical workflow process and analysis

Q#	Statement
B1	How would you characterize your knowledge and background on clinical workflow process and analysis?
B2	How would you characterize your knowledge and background on process mining?
H1	The content materials on clinical workflow gave me a better appreciation for the usefulness of methods, tools, and technologies.
H2	I am more aware of the potential for workflow analysis, design, and improvement to benefit health communities.
H3	I am more interested and motivated to analyze, design, and improve clinical workflow processes using software and tools.
H4	Participating in this course inspired me to use my information technology skills to help health communities.
H6	I enjoy working on clinical process mining tools such as Disco because it will allow me to see process visually and identify bottlenecks.
H7	Working on hands-on and writing assignments increased my interest in clinical workflow analysis and redesign.
H8	Working on the term project increased my confidence in applying my gained knowledge and computing ability to address issues in the healthcare domains.
H9	Completing this course (IT6523) encouraged me to consider taking advanced courses in the health informatics and health IT fields.

H10	The subject matter of clinical process and workflow is highly relevant to my current and/or future career plans.
H11	I have a high level of experience in the clinical process and workflow analysis subject matter.
H12	Overall, I am satisfied with my learning in the IT6523 course.

Table 2: Survey questions

The reflection on student’s perception of content, effective learning and interests were captured with twelve questions (H1-H12, See Table 2). We found that most of the participating students agreed or strongly agreed with these questions. For example, Figure 8 shows the result of whether the content materials on clinical workflow gave students a better appreciation for the usefulness of methods, tools, and technologies.

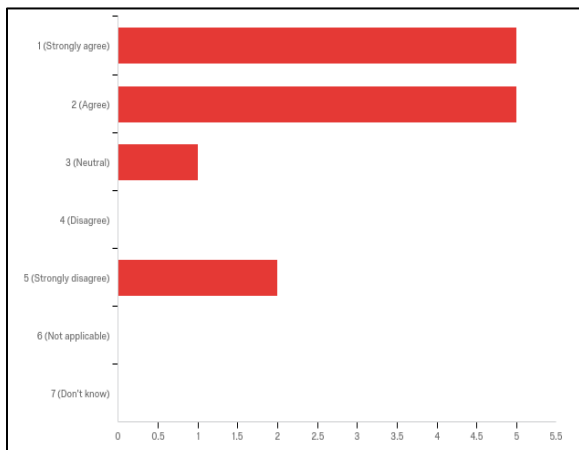


Figure 8: Survey response – Question H1

Similarly, Figure 9, 10, 11, 12, and 13 show the response of the questions H3, H4, H6, H8, and H11, respectively.

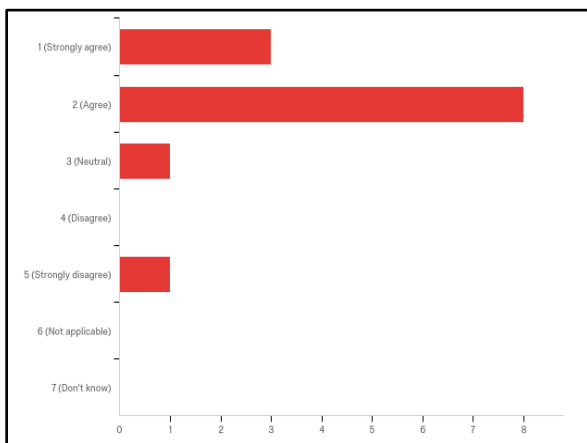


Figure 9: Survey response – Question H3

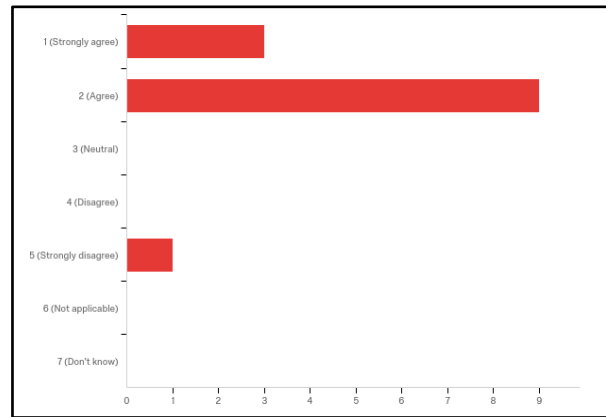


Figure 10: Survey response – Question H4

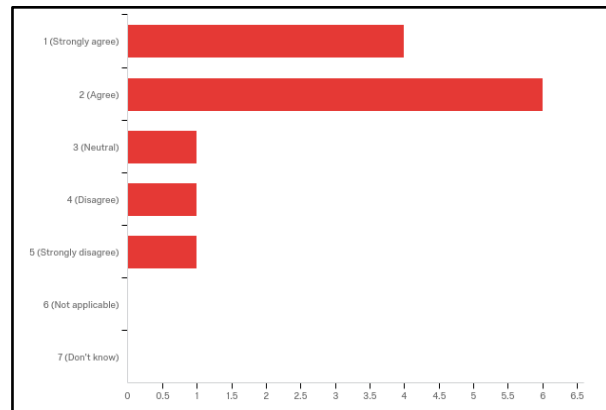


Figure 11: Survey response – Question H6

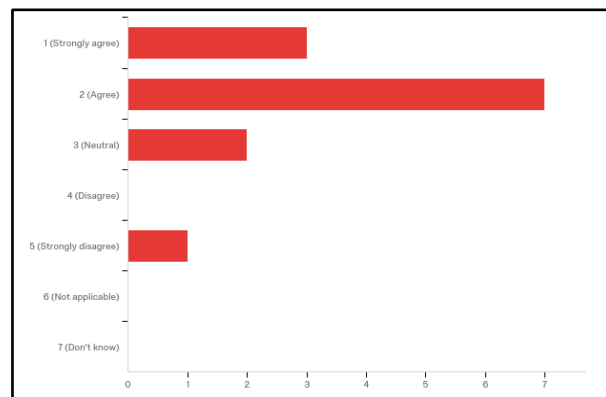


Figure 12: Survey response – Question H8

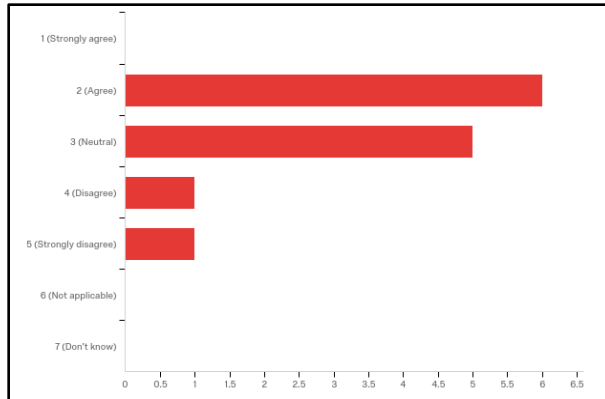


Figure 13: Survey response – Question H11

We also received some feedback. Below we provide some of the received comments in the survey that are highly encouraging.

Good lecture materials and assignments.

Content was useful for my job in healthcare.

Informative reads, articles and ppt.

This course was excellent for me. It gave me a great work-out with this topic – the exercises were very appropriate and the lectures were good and informative.

Overall, we find the developed module and assessments were effective to learn workflow analysis using process mining techniques.

5. CONCLUSIONS

There is a need to develop innovative learning materials for teaching healthcare topics. Effective teaching of workflow analysis is crucial to support the mission of delivering high quality and cost-effective services to patients. This paper introduced learning module that leverages process mining to perform workflow analysis and improve process by identifying bottlenecks. We applied the developed module in a graduate course and the initial results and feedback from students show positive and encouraging. We plan to apply more tools and algorithms related to mining towards workflow analysis and redesign in the future.

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