# Visual Analytics in Medical Education: Impacting Analytical Reasoning and Decision Making for Quality Improvement

Christos VAITSIS[a,1], Gunnar NILSSON[b], Nabil ZARY[a]

[a]*Department of Learning Informatics Management and Ethics, Karolinska Institutet, Stockholm, Sweden*
[b]*Department of Neurobiology, Care Sciences and Society, Karolinska Institutet, Stockholm, Sweden*

**Abstract.** The medical curriculum is the main tool representing the entire undergraduate medical education. Due to its complexity and multilayered structure it is of limited use to teachers in medical education for quality improvement purposes. In this study we evaluated three visualizations of curriculum data from a pilot course, using teachers from an undergraduate medical program and applying visual analytics methods. We found that visual analytics can be used to positively impacting analytical reasoning and decision making in medical education through the realization of variables capable to enhance human perception and cognition on complex curriculum data. The positive results derived from our evaluation of a medical curriculum and in a small scale, signify the need to expand this method to an entire medical curriculum. As our approach sustains low levels of complexity it opens a new promising direction in medical education informatics research.

**Keywords.** Visual analytics, medical education, analytical reasoning, decision making.

## Introduction

Undergraduate medical education is a complex system that constantly needs to be evaluated and transformed to follow the fast pace of changing healthcare. The medical curriculum, as the main instrument in hands of medical teachers for planning, designing and delivering learning and assessment activities towards the learning outcomes is inherently complex and thereby unexploited for analysis and decision support concerning changes and improvements in medical education [1],[2]. In a previous study we reported the limited use of curriculum data for such purposes and we demonstrated how visual analytics (VA) as a new research field can be applied to analyze and visualize a medical curriculum [3]. We also applied VA at the level of competencies and learning outcomes of an undergraduate medical program with possible positive effects on reducing the curriculum's complexity by creating networks of information representing the curriculum. Previous studies have used VA in higher

---

[1] Corresponding Author: Christos Vaitsis, Department of Learning, Informatics, Management and Ethics, Centre for Learning and Knowledge, Karolinska Institutet, Berzelius väg 3, Stockholm, Sweden; christos.vaitsis@ki.se.

education, in one case to investigate student retention and graduating levels [3], and in another case to investigate the continuity of patient care through a VA design process [4].

However, even though efforts have been made, the potential of applying VA in a medical curriculum and measuring its impact on analytical reasoning to support and inform decisions in medical education has not been specifically addressed and determined.

The aim of this study was therefore to evaluate and determine possible impact in analytical reasoning and decision making among teachers using VA for medical curriculum data representations.

## 1. Methods

### 1.1. Data collection

We designed and performed our study based on three visualizations of curriculum data from the undergraduate medical program at Karolinska Institutet (KI) [6]. We performed a literature review to identify variables that are able to affect perception and cognition and impact on analytical reasoning and decision making through VA. The identified variables derived from Romero et al. [7] and Card et al. [8] .

To determine the effect and impact of VA on analytical reasoning and decision making we used both qualitative and quantitative approaches with the three visualizations. We firstly conducted four (4) semi-structured interviews, with participants from undergraduate medical program at KI. We used the purposeful sampling technique [9], in order to select people with characteristics required to answer questions concerning the effect of the analysis and visualization of the medical curriculum. Therefore the participants were course/program directors and teachers involved in medical curriculum design, implementation and improvement.

As an additional data collection tool we used a questionnaire after presenting the data in two different cases. Firstly, in a poster presentation in a yearly educational congress at KI for teachers and directors in medical education, and secondly after a power point presentation in a regular meeting of people working at KI's central educational administration, resulting in twenty seven respondents.

Both in interviews and questionnaire the curriculum data before and after the VA intervention were presented and explained in order to give a clear picture of what data had been used and the outcome of the three visualizations.

### 1.2. Data Analysis

Having the identified variables from previous section in mind, we developed the interview and questionnaire guides. To analyze the collected data from the four interviews we used Thematic Content Analysis (TCA) [10]. This resulted in creating five themes under which we grouped interviewees' answers and presented in results section. We then analyzed the answers from questionnaire according to quantitative data analysis suggested by Walliman [11]. The questions had predefined answers using Likert scale [12], and we counted and grouped the outcomes for each question under the identified theme. The last question of the questionnaire is presented along with

given answers in the results section separately and under no theme as a question asking of general impression of respondents.

## 2. Results

### 2.1. Identified variables

The variables identified from literature review as sign for enhancement of perception and cognition to impact on analytical reasoning and decision making through VA were:

- Increased cognitive resources (V1)
- Decreased need to search for information (V2)
- Enhancement of the recognition of patterns (V3)
- Easier perception of inference of relationships (V4)
- Increased ability to explore and manipulate the data (V5)

### 2.2. Interviews

In Table 1 we present the five themes produced by the TCA analysis of interviews, their matching to identified variables above and some indicative comments from interviewees for each theme:

**Table 1.** Themes, variables and comments of the interviewees.

| Theme | Matching variable(s) | Comment |
|---|---|---|
| Recognition of depicted information | V3 | Easily recognizable. |
| Perception of patterns and relations | V1, V4 | It describes the course and how to plan it, it can help to overview and plan the course and it could be valuable for students when the course is running. |
| Information search | V2 | Searching for information using the visualizations is 100 times better. It's not only better. This is a way to have everything at the same place. Because if you try to get everything in one place as it is right now is almost impossible. |
| Gap analysis | V3, V4, V5 | I think this is very interesting because it gives you an overview of what we're doing, so I think this a very good tool. This is a really easy and elegant way to see what learning outcomes are not taught but assessed. |
| Constructive alignment | V3, V4, V5 | I can never find this information in the curriculum. I have to sit down and try to do it but I can never have the clear picture I get from these visualizations. I don't think I can manage that. |

### 2.3. Questionnaire

In Table 2 we present the answers from the questionnaire analysis. We only present percentages of positive and neutral answers as no negative answer were given to any of

the questions. Positive answers correspond cumulatively to "Strongly agree" and "Agree" and neutral answers to "Neither agree nor disagree" from the Likert scale.

**Table 2.** Percentages of positive and neutral questionnaire answers for the identified themes.

| Theme | Positive answers (%) | Neutral answers (%) |
|---|---|---|
| Recognition of depicted information | 81 | 19 |
| Perception of patterns and relations | 77 | 23 |
| Information search | 81 | 19 |
| Gap analysis | 92 | 8 |
| Constructive alignment | 85 | 15 |

Answers on the last question of the questionnaire (*To what extent do you agree that the presented approach can support teachers and directors to perceive, recognize and analyze the structure of the examined course, thus improve the decision making upon the constructive alignment of the course*?) were as follows: Strongly disagree 0 %, Disagree 0 %, Neither agree nor disagree 3,0 %, Agree 52,0 %, and Strongly agree 45,0 %.


## 3. Discussion

Our results put forward that VA can be used as a tool to support analytical reasoning and decision making in the context of medical education. The identified variables appear to be verified in a satisfactory level by the positive answers of the participants, who easily perceived the enhanced by VA relationships and patterns within the curriculum data from the pilot course. This encourages future research on how the presented approach for curriculum data analysis and visualization can be expanded to cover an entire medical curriculum in order to support a more general analytical reasoning and decision making of instructors in medical education.

Recognizing curriculum information as easily as proved in our case can support teachers and directors to understand parts of the medical curriculum beyond what they are responsible for. This may contribute to an improved general understanding of how different parts of the curriculum bind together in the big picture of the curriculum. The perception of overall patterns and relations can support teachers in identifying paths that would help them describe and analyze the curriculum. In particular they may perform analysis that may help in planning and making more thorough decisions. [13]

### 3.1. Impact on Analytical Reasoning

VA allows teachers and directors to easily perceive the structure of the medical curriculum, define how each part coexists as part of a network of different curriculum parts and reason for its use and importance in the curriculum. VA also helps to better understand teachers' role and the consequences of delivering their part without being able to determine how it can be harmonized with other parts in medical education. Understanding their part better through the ways their teaching and assessment is depicted towards the common learning outcomes, contributes to the common purpose of creating health professionals able to meet healthcare demands.

## 3.2. Impact on Decision making

VA supports teachers and directors first of all to decide how to cope with discrepancies and structure anomalies revealed from gap analysis and the existence or not of the constructive alignment in the curriculum. Further to better see how planned activities fit or not fit in the curriculum, and also support decisions about the level of achievement of learning outcomes. Finally, VA also can display needed changes and create a better picture of a future medical curriculum in order to deliver a medical education in pace with healthcare demands. [14]

## 4. Conclusion

VA appears to have a pronounced positive impact on analytical reasoning and decision making among teachers, when used to represent key aspects of a medical curriculum. The identified variables were realized through the themes produced by the evaluation of three visualizations of curriculum data to a satisfactory extent. This implies the need to apply VA to an entire medical curriculum and address the challenge of understanding an even more complex system, and to evaluate VA as a tool for more overarching quality improvement purposes.

## References

[1] Maojo V, Martín F, Crespo J, Billhardt H. Theory, abstraction and design in medical informatics. Methods Inf. Med. 2002 Jan; 41(1):44–50.

[2] Mennin S. Self-organisation, integration and curriculum in the complex world of medical education. Med. Educ. 2010;44(1):20–30.

[3] Vaitsis C, Nilsson G, Zary N. Big data in medical informatics: improving education through visual analytics. Stud Health Technol Inform. 2014;205:1163-7.

[4] Géryk J, Popelínský L. Visual Analytics for Increasing Efficiency of Higher Education Institutions. In: Abramowicz W, Kokkinaki A, editors. Business Information Systems Workshops. Lecture Notes in Business Information Processing. 183: Springer International Publishing; 2014. p. 117-27.

[5] Olmos, M., & Corrin, L. (n.d.). Learning Analytics: a case study of the process of design of visualizations, 16(3), 39–49.

[6] Vaitsis C, Nilsson G, Zary N. (2014) Visual analytics in healthcare education: exploring novel ways to analyze and represent big data in undergraduate medical education. PeerJ 2:e683 http://dx.doi.org/10.7717/peerj.683; Figure 4,Teaching methods and learning outcomes (taught and non-taught) of the CM-RD course, p. 14; Figure 5, Questions in written examination, learning outcomes (assessed and non-assessed) and main outcomes of the CM-RD course, p. 15; Figure 6, Constructive alignment and gap analysis of the CM-RD course, p. 16

[7] Romero C, Ventura S, Pechenizkiy M, Baker RSJD, editors. Handbook of educational data mining 1st ed Chapman & Hall/CRC Data Mining and Knowledge Discovery Series;2010 Chapter 2, Visualization in educational environments. p. 9-27

[8] Card SK, Mackinlay JD, Shneiderman B. Readings in information visualization: using vision to think: Morgan Kaufmann; 1999.

[9] Koerber A, McMichael L. Qualitative Sampling Methods: A Primer for Technical Communicators. Journal of Business and Technical Communication. 2008;22(4):454-73.

[10] Anderson R. Thematic Content Analysis (TCA): Descriptive Presentation of Qualitative Data. :1–4

[11] Walliman N. Research Methods: The Basics. London and New York: Routledge; 2011. Chapter 6, The Nature of Data. p. 190

[12] Likert scale [Internet], http://en.wikipedia.org/wiki/Likert_scale [accessed 3 Oct 2014]

[13] Börner K. Visual Analytics in Support of Education. 2010;2–3.

[14] Ware C. Information Visualization: Perception for Design 2nd ed. Morgan Kaufmann Interactive Technologies Series; 2004 Chapter 11, Thinking with Visualizations p.351-87