THEORETICAL UNDERPINNINGS OF VISUALISATION TO PROMOTE MEANINGFUL LEARNING: A SYSTEMATIC LITERATURE REVIEW PROTOCOL

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ABSTRACT

This paper illustrates the protocol of conducting systematic review on theoretical underpinnings of visualisation to promote meaningful learning. The systematic review demonstrates how previous scholars used visualisation to deliver meaningful learning in higher education institutions. Visualisation emerges as one of the new dominant technologies in higher education to enhance learning. Visualization increases learning interactions by encouraging students to connect and engage the learning materials with their prior knowledge, peers and environment. Meaningful Learning suggests that students to be supported with suitable tools and relevant information, so that they build knowledge through a strong framework by connecting the new context with the old ones, and be able to apply the knowledge in the life. The systematic review highlights the considerations that need to be addressed when planning successful meaningful learning assisted by visualisation in higher education institution. Based on the result, the lack of theoretical and pedagogical understanding will make visualisation and meaningful learning unsuccessful. Careful and deliberate planning of visualisation is also required to create a meaningful learning experience among students.

1   INTRODUCTION

Meaningful learning promote students to relate their new knowledge to prior knowledge and stimulate the learning experience so students are able to apply the learned concepts in real life environments (Galloway & Bretz 2015). Meaningful learning opposes rote learning where students usually learn to pass the course and unable to retain the knowledge for daily application (Schuster et al. 2018). Considering that many students in technical subjects like data analytics courses are engaged in rote learning, meaningful learning environment is needed to develop effective statistical reasoning and problem solving skills. In this approach, students are giving their commitment to give meanings to the learned concepts by relating to their experience, to help students to retain the knowledge to be applied in future study, daily dealings and incoming careers.

Visualization presents information or data using illustrations to easily capture important messages rather than the text form (Attallah 2017). Visualisation appears as one of the dominant technologies in higher education learning by optimizing visual elements to enhance interactive capabilities to enable students to benefit from the learning materials (Tarling & Ngambi 2016). Visualization increases learning interactions by encouraging students to connect and engage the learning materials with their prior knowledge, peers and environment.

Although visualisation plays important role in creating meaningful learning experiences among students, not much understanding is gained in the successful implementation in higher learning institution. While several SLR studies were conducted as early as 2010, such as [6, 10], these prior research have provided deep insight on visualization. However the focus on meaningful learning has been very minimal and has not gained enough attention among research. As we embarked on this methodologically rigorous review process, our aim was not merely to aggregate the clear evidence regarding visualisation techniques available from the existing literature but also to encourage researchers to undertake further systematic literature review (SLR) studies in meaningful learning that can serve as a guide for its implementation in higher education studies. The objective of the study is to establish strategies for utilising visualisation to promote meaningful learning. The paper elaborates the protocol in conducting systematic literature review on the topic.

2.   LITERATURE REVIEW SURVEY

Aim

The systematic literature review aims at examining previous research to response to the identified questions:

What theoretical underpinnings could be adopted in the application of visualisation to promote meaningful learning in higher education institutions?

The study refines the research questions based on these criteria: population, interventions, comparison, outcomes and PICOS study designs (Liberati et al. 2009).

Objectives

The main objective of this review was to identify pedagogical background to undertake visualisation for exposing undergraduate students in higher learning institutions with meaningful learning experience.

Research Question

One of the objectives of this study is to investigate the visualisation techniques applied in meaningful learning. Thus, the research questions raised in this study merges from this issue. List of questions were raised by previous research such as (Akbar et al. 2012) that emphasises significant role of visualisation in learning. This study focuses on pedagogical aspects, learning cultures, effectiveness of visualization in higher education learning, difficulties and challenges, and future lines of work in the field of visualization in meaningful learning.

The research questions (RQs) addressed in the study are as follows:

RQ1. How many primary SLR studies on visualization in learning have been there since 2010?

RQ2. What are the difficulties in visualization techniques based on reviewed studies?

RQ3. How does the visualisation technique address meaningful learning in higher education context?

RQ4. What are the theoretical underpinnings of the study?

RQ5: What are the limitations of current research?

3.   LITERATURE REVIEW DESIGN

This systematic literature review applies the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). PRISMA serves as a guideline for study selection process in systematic literature review studies. PRISMA outlines the search strategy, inclusion and exclusion criteria, eligibility, data collection and analysis (Moher et al. 2015).

The review utilises major electronic databases, namely Springer, IEEE, Science Direct, Google Scholar, Wiley, and ACM. Keywords in the title and abstract included in the quest method include "visualiation," "meaningful learning" and "higher education". The search gather a total of 110 documents from the identified sources as presented in Table 1.

Table 1: Database search

Platform	Frequency
Springer	155
IEEE	245
Science Direct	132
Google Scholar	1700
Wiley	830
ACM	271
Total	3333

Types of studies in the search limit eligible previous research. The eligible studies will be randomized studies and non-randomized studies (prospective and retrospective cohort studies, case–control studies, cross-sectional studies, before and after comparison), observational studies and surveys. The search includes all studies including learning intervention that involve higher learning institutions. Also teaching strategies and methodologies aimed at developing visualisation in promoting meaningful learning.

Results regarding Meaningful Learning, seen as a structured combination of six types of learning and characterized by 'intentional', such as clear aim to conduct learning for self development; çonstructive' i.e. understanding and remembering information and ideas by giving meaning to the learned concepts; the ability to collaborate with others which generates critical, creative and/or practical thinking; 'authentic', that is the ability to connect concepts, ideas, people and experiences, which offers students applicable skills; 'active', engage as learning more about doing it yourself and interact with the learning materials (Sun et al. 2013).

The search include several inclusion and exclusion criteria as part of screening process. Analysis of the research contents identifies relevancy and contribution of the selected documents based on the research questions. The process procduces 110 papers from 578 identified papers that met the criteria related to the theoretical underpinnings of visualisation in meaningful meaning. Inclusion and exclusion criteria are presented in Table 2.

Table 2: Inclusion and Exclusion criteria

| Criterion	Eligibility	Exclusion
Literature type	Journal	Book series, private access articles, citations and different kevword
Language	English	Non-English
Timeline	2015-2020	Before 2015
Subject area	Educational technology, learning and instruction, instructions in higher institutions	Òther than Educational technology, learning and instruction, instructions in higher institutions.
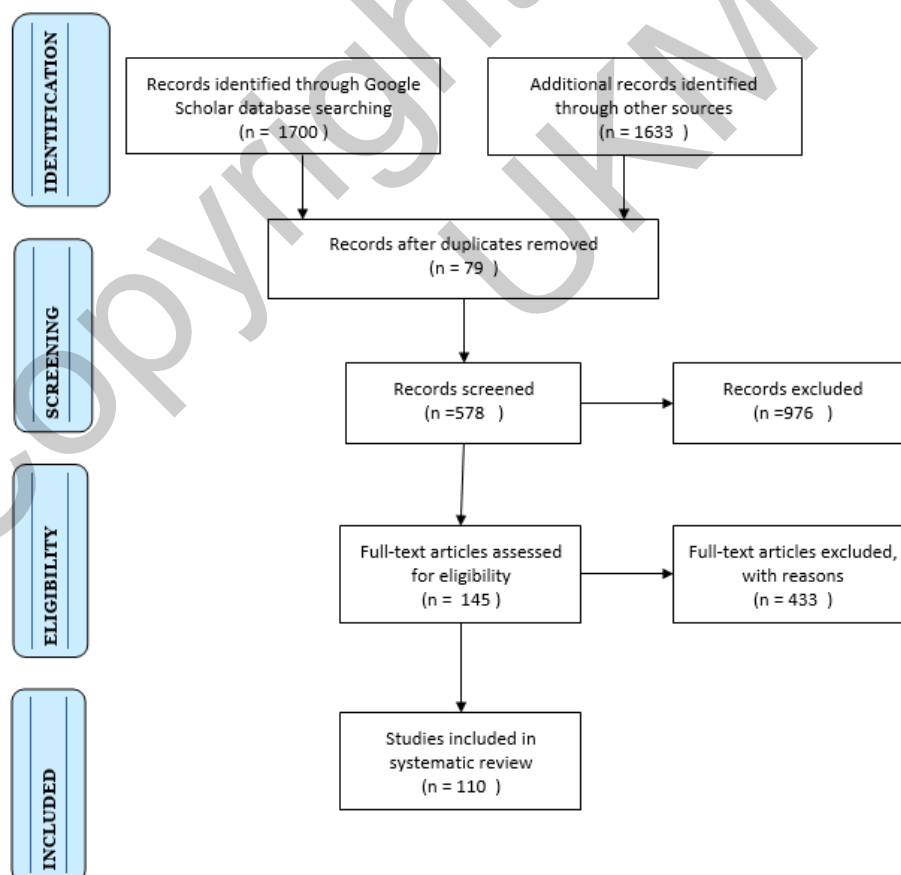
Figure 1: PRISMA Flow Diagram (adapted from Moher et al., 2015)

4. RESULTS

Summary of Studies are presented in Tables 3 to 5 by presenting the institution backgrounds, research topic and year of the literature. Many of the studies focus on visual tool, concept map, dynamic visual, visual application, visual content and visual literacy. The results are separated to organise the materials based on the sources.

Table 3: Studies 1 to 35

No	Institution	Country	Topic area	Author	Year
1	Kansas State University	USA	concept map	Biniecki & Conceição	2015
2	University of Michigan	USA	dynamic visual	Wu et al	2019
3	Catholic University of Ávila	Spain	dynamic visual	Vergara et al	2019
4	Bond University	Australia	visual device	James et al	2017
5	Riga Technical University	Latvia	visual tool	Veide and Strozheva	2016
6	East China Normal University	China	visual app	Sun and Wang	2016
7	École polytechnique fédérale de Lausanne	Switzerland	concept map	Schwendimann	2015
8	Indian Institute of Technology Bombay	India	visual tool	Banerjee et al	2015
9	University of Nebraska Lincoln	USA	visual tool	Olmanso et al	2016
10	Dublin City University	Ireland	visual tool	Rice	2016
11	University of Jyv€askyl€a	Finland	visual literacy	Kędra and Žakevičiūtė	2019
12	University of Houston-Clear Lake	USA	concept map	Wie and Yue	2017
13	Universiti Teknologi Malaysia	Malaysia	visual aid	Kashefi et al	2015
14	University of Tartu	Estonia	visual content	Hooshyar et al	2019
15	Swansea University	UK	dynamic visual	Fırat and Laramee	2018
16	Mataram University	Indonesia	visual tool	Anwar et al	2018
17	Ağrı İbrahim Çeçen University	Turkey	visual app	Ocal	2017
18	Palestine Technical University-Kadoorie	Palestine	dynamic visual	Shraim and Crompton	2015
19	Stockholm University	Sweden	visual tool	Olsson et al	2015
20	Macquarie University	Australia	visual app	Stevenson et al	2015
21	Prince Sultan University	Saudi Arabia	visual tool	Eilouti	2018
22	Central Queensland University	Australia	visual tool	Munoz et al+D24	2016
23	King Abdulaziz University	Saudi Arabia	flipped classroom	Al-zahrani	2015
24	National Taiwan Normal University	Taiwan	visual analytics	Hsiao et al	2017
25	Inha University	South Korea	visual tool	Jin	2017
26	Universitätsplatz	Germany	visual tool	Steinert et al	2020
27	NA	Iran	visual organiser	Roohani	2015
28	Logosnet Turin	Italy	visual image	Salvetti and Bertagni	2017
29	University of Queensland	Australia	visual device	Isaías and Isaías	2018
30	King's College London	UK	concept map	Hay et al+D32	2015
31	University of Surrey	UK	concept map	Kinchin and Kinchin	2015
32	University of the Sunshine Coast	Australia	dynamic visual	Scha	2017
33	InstitutTeknologi Brunei	Brunei	visual content	Wan	2015
34	Griffith University	Australia	visual tool	Naug et al	2016
35	City University of Macau	China	visual tool	Peng et al	2019

Table 4: Studies 36 to 69

No	Institution	Country	Topic area	Author	Year
36	Bangor University	UK	visual tool	Roberts et al	2018
37	Kyushu University	Japan	visual content	Wang	2017
38	Universiti Teknologi PETRONAS	Malaysia	blended learning	Afsharian	2017
39	University of New South Wales	Australia	visual content	Tran and Meacheam	2020
40	University of Sydney	Australia	visual analytics	Pardo et al	2016
41	Instituto Tecnol´ogico de Costa Rica	Costa Rica	concept map	Navas et al	2018
42	TU Dresden	Germany	dynamic visual	Lenk	2018
43	East China Normal University	China	dynamic visual	Zhao and Lin	2020
44	University of St Gallen	Switzerland	visual tool	Hoidn	2017
45	University of California	USA	concept map	Schwendimann	2019
46	Universidad de Zaragoza	Spain	visual content	Belanche et al	2020
47	National Kaohsiung Normal Univ.	Taiwan	metavisual	Hung and Chang	2019
48	Universidad Industrial de Santander	Colombia	visual tool	López et al	2020
49	Karolinska Institutet	Sweden	visual aid	Hyll et al	2019
50	University of San Francisco	USA	visual tool	Mattis	2015
51	University of OulU	Finland	visual tool	Järvenoja et al	2017
52	University of Reading	UK	visual tool	Hackl and Ermolina	2019
53	University of Tartu	Estonia	visual analytics	Hooshyar et al	2020
54	Far East University	Taiwan	concept map	Hsieh	2016
55	Far East University	UK	concept map	Deplano	2018
56	Pedagogical University of Tyrol	Austria	visual tool	Andre et al	2019
57	Universiti Kebangsaan Malaysia	Malaysia	visual content	Hamdan et al	2015
58	University of South Carolina	USA	visual tool	Khalil and Elkhider	2019
59	University of Hong Kong	Hong Kong	visual content	Tan and Hew	2016
60	University of Toledo	USA	visual content	Sullivan	2018
61	Ganesha University of Education	Indonesia	dynamic visual	Sudatha et al	2018
62	University of Alberta	Canada	visual content	Montgomery et al	2015
63	Virginia Commonwealth University	USA	visual image	Taylor	2018
64	Leibniz-Institut f€ur Wissensmedien	Germany	visual tool	Schüler et al	2019
65	Tamkang University	Taiwan	concept map	Shaw	2019
66	University of Surrey	UK	concept map	Kinchin et al	2015
67	Nevsehir Haci Bektas Veli University	Turkey	concept map	Aydoğdu and Güyer	2019
68	Michigan State University	USA	concept image	Burrill	2019
69	University of Wisconsin - Milwaukee	USA	concept map	Daley et al	2016

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Table 5: Studies 70 to 110

No	Institution	Country	Topic area	Author	Year
70	University of South Carolina	USA	visual cues	Arslan-Ari	2018
71	Troy University	USA	visual literacy	Aisami	2015
72	Ahi Evran University	Turkey	concept map	Islim	2018
73	Coastal Carolina University	USA	visual narratives	Everett	2017
74	Leibniz-Institut f€ur Wissensmedien T€ubingen	Germany	visual tool	Scheiter and Schleinschok	2017
75	University of North Dakota	USA	visual tool	Clinton et al	2018
76	The University of Hong Kong	Hong Kong	concept map	Wang et al	2017
77	University of Arkansas	USA	concept map	Roessger et al	2018
78	Near East University	Cyprus	digital concept map	Gülsüm	2019
79	University of California	USA	visual tool	Nolan and Perrett	2016
80	St. Kliment Ohridski University	Bulgaria	concept map	Ivanovska	2019
81	Kabarak University	Kenya	visual organiser	Kigo et al	2018
82	Pattimura University	Indonesia	visual organiser	Souisa	2020
83	University of Queensland	Australia	visual organisers	Awidi et al	2020
84	University of Twente	Netherland	visual organiser	van der Meij	2019
85	Kuvempu University	India	visual organiser	Somashekhara & Dange	2018
86	Universitas Mataram	Indonesia	visual organiser	Gunawan et al	2020
87	Universitas Mataram	Indonesia	visual organiser	Kusdiastuti et al	2020
88	University of Twente	Netherland	visual organiser	Li	2016
89	University of South Alabama	USA	visual organisers	Bullard	2018
90	Universitas Mataram	Indonesia	visual organiser	Nisyah et al	2020
91	Nihon University	Japan	visual organiser	Shinogaya	2018
92	Universitas Islam Negeri Raden Intan Lampung	Indonesia	visual organiser	Thahir et al	2020
93	Adwa College of Teacher Educatio	Ethiopia	visual organiser	Gidena	2019
94	Hebrew University of Jerusalem	Israel	visual tool	Wajner	2019
95	University of Salamanca	Spain	dynamic visual	Extremera et al	2020
96	École polytechnique fédérale de Lausanne	Switzerland	concept map	Schwendimann & Linn	2016
97	Indian Institute of Technology	India	visual tool	Banerjee and Murthy	2018
98	University of Copenhagen	Denmark	concept map	Stevenson et al	2017
99	Universiti Utara Malaysia	Malaysia	visual content	Al-Sakkaf et al	2019
100	Universiti Utara Malaysia	Malaysia	visual content	Al-Sakkaf et al	2019
101	Universit´e du Qu´ebec `a Chicoutimi	Canada	visual content	Bedu et al	2019
102	Universiti Utara Malaysia	Malaysia	visual content	Al-Sakkaf et al	2018
103	Universidad Rey Juan Carlos	Spain	visual content	Velázquez-Iturbide et al	2017
104	Ondokuz Mayıs University	Turkey	visual content	Rezan Yilmaz and Ziya Argun	2018
105	Comenius University, Bratislava	Slovak Republic	specific visual appp	Gunčaga et al	2018
106	Hong Kong University of Science and Technology	Hong Kong	specific visual appp	Lo et al	2018
107	Comenius University	Slovak Republic	visual content	Fuchsova and Korenova	2019
108	University of Prishtina	Kosovo	visual content	Shatri and Buza	2017
109	Lazarian Dnipro National University	Ukraine	visual content	Moslina	2020
110	Dalian Polytechnic University	China	visual content	Liu et al	2020

5.   CONCLUSIONS

This protocol of the literature review iustrates four phases (analysis, design, development, and evaluation) detailing main characteristics in each of them. The protocol guide researchers to obtain results of SLR that are essential for the development of visualisation to support meaningful learning because many aspects in the research are not yet been explored extensively. The SLR serves as a baseline for new development of learning module that incorporate visualisation features most effective in promoting meaningful learning.

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