 doi:10.20944/preprints202208.0198.v1

Article

Thematic analysis of Indonesian physics education research literatures using machine learning

Purwoko Haryadi Santoso * , Edi Istiyono , Haryanto Haryanto , Wahyu Hidayatulloh

Abstract: Emergent physics education research (PER) literatures have been disseminated through academic publications within the community. The growing body of literatures over years challenge Indonesian PER scholars to understand how the research community has been progressed and what possible future work that should be emphasized. Nevertheless, previous traditional method of thematic analysis performed serious limitation when the number of PER literatures exponentially increased. Dealing with this large volume of publications, one of the machine learning studies namely natural language processing (NLP) was employed in this study to automate our thematic analysis among Indonesian PER literatures that are still limited to be explored. One of the well-known NLP algorithm, latent Dirichlet allocation (LDA), has been performed to extract Indonesian PER topics and their associated development between 2014 and 2021. A total of 852 papers (~ 4 to 8 pages each) were collectively downloaded from five international conference proceedings organized by Indonesian PER researchers. Before their topics were modeled through LDA algorithm, our data corpus should be previously preprocessed through several common procedures of established NLP studies. Findings revealed that LDA has thematically quantified Indonesian PER topics and described their distinct development over certain period. The identified topics from this study demonstrated that Indonesian PER community has established robust development in eight distinctive topics to the present. They begin with initial interest in focusing research on physics laboratory and following the research based instruction in the late 2015. Indonesian PER scholars sustained to study continuous topic on 21st century skill until 2019 which gave way to a focus on developing relevant educational technology to address several forms of students' performance including scientific literacy and problem solving. There is still lack of Indonesian PER literatures that have been attempted to address qualitative aspects of physics teaching and learning.

Keywords: thematic analysis, Indonesia, physics education research, natural language processing

1. Introduction

Several decades of physics education research (PER) have established enormous body of literature related to physics teaching and learning. In the context of international PER communities, many thousands of PER literatures have been published in several high impact journals such as *The Physics Teacher* (TPT), *The American Journal of Physics* (AJP), and *Physical Review Physics Education Research* (PRPER) (previously announced as *Physical Review Special Topics Physics Education Research*) since 1933, 1963, and 2005 respectively. Within the context of Indonesian PER literatures, since 2014 to date, several annual international conferences in the areas of PER and others science, technology, engineering, and mathematics (STEM) discipline based education research have been routinely organized by several Indonesian Teacher Education Institutions (TEIs). The five oldest conferences comprise of *International Conference on Research, Implementation, & Education of Mathematics and Science* (ICRIEMS, since 2014) [1] and *International Seminar on Science Education* (ISSE, since 2015) organized by Universitas Negeri Yogyakarta (UNY) [2], *International Conference on Mathematics & Science Education* (ICMSE, since 2014) organized by Universitas Negeri Semarang (UNNES) [3], *International Conference on Mathematics and Science education* (ICMScE, since 2016) organized by Universitas Pendidikan Indonesia (UPI) [4], and *International Conference on Mathematics and Science Education* (ICoMSE, since 2017) organized by Universitas Negeri Malang (UM) [5]. These number of international

 doi:10.20944/preprints202208.0198.v1

conferences have substantially contributed to our international insights of research knowledge within Indonesian PER field instead of peer reviewed journals that were merely published nationally during the same period of time. They have attracted various PER scholars across novice researchers (graduate students) and experts on PER professorship that were funded through research grants from Indonesian Ministry of Higher Education. The authors have been affiliated from several parts of Indonesian institutions and neighboring countries particularly in the region of Southeast Asia.

This volume of publications provides a convincing challenge for PER scholars until they might have limited time to follow the updates of recent paper. Moreover, it is troublesome for them in discovering whole articles that might be related to their needs. Most researchers sometimes tend to find out the most impactful research articles for their relevant works. There is always a possibility that they have surpassed some missed resources within the collection of literature that might contribute more for the field yet out of their attention. These cases are more complicated for novice researchers in which they should exhaustively review the long journey of the fields [6]. As a consequence, they are usually more dependent on the given suggestions whether by communities, research groups, or indexing databases like Google Scholar [7].

On the other hand, this number of works also offer some opportunities about the horizon of PER development. They could exhibit that PER field has currently developed to the phase of maintaining a robust experience of theoretical and methodological practice through their existence for certain time. Hence, this body of literature could explain the history of PER field and development of their topics over time. To synthesize the comprehensive story of PER topics in the international context, one may consult the previous ambitious works that has been disseminated by McDermott & Redish [8], Docktor and Mestre [9], Meltzer and Otero [10], and Odden et al. [11]. Those great works admittedly have guide PER community in several parts of the world. Nevertheless , the representative Indonesian scholars in these international publications were still limited to capture the Indonesian PER context. To that reason, it might be relatively less appropriate to understand the development of Indonesian PER topics if we merely consider those resources without eliciting the context of Indonesian PER scholars.

Additionally, to the best of our knowledge, Indonesian PER researchers have not yet performed this similar work to analyze their literatures. This may be constrained either by the complication of expanding published papers or their attempts are still progressing. One may assume that it is kind of inefficient way to conduct thematic analysis through reading and summarizing the entire PER literatures traditionally. Recent study on science education research by Faisal et al. [12] even argued that performing this kind of analysis on the large number of articles was “tricky” as mentioned in their introduction of a paper about mapping the research trends on Indonesian science education research. Hence, they considered that the descriptive analysis approach on the keywords of the announced title of research grants was more doable to simplify their content analysis study. In their conclusion, Faisal et al. [12] also conceded that their selection of this kind of analysis was unable to represent the final of research disseminations. The initial title of research grants were more likely to be improved after the works had been finished. Either theoretical or methodological considerations made it possible some improvements occurred. Publications of their works might be slightly dissimilar with the proposed title from the initial announcement of research grants.

Within other PER related fields, the descriptive analysis approach also has been approached by some trends analysis on particular topics such as scientific literacy [13], teacher education [14], or learning media [15]. In addition to the aforementioned limitation, this method fails to represent the nature of research topics that should be in terms of mixture of words instead of a single keyword [16]. Consequently, there needs to be several words to represent a literature topic. This is known as the distributional hypothesis of topics that has been established by the linguistics field [17]. Therefore, the mixed membership’s idea and the distributional hypothesis of topics should be consulted

 doi:10.20944/preprints202208.0198.v1

to shed more light on the analysis of literature topics. To that reason, a new more efficient and significant method or algorithm has been approached in this paper.

Recently, natural language processing (NLP), a subfield of machine learning studies, has proposed method of thematic analysis to extract our understanding on textual data from large collection of literature. Recent studies by Odden et al. have performed this kind of analysis towards physics education research conference (PERC) proceeding [11] and 100 years journey of *Science Education* journal [18]. In this study, we extend these efforts to cope with the context of Indonesian PER literatures. We have performed one of the unsupervised NLP algorithms, latent Dirichlet allocation (LDA) [19,20], to automatize thematic analysis of the Indonesian PER literatures derived from five international conference proceedings published between 2014 and 2021. Throughout the LDA topic modeling, we have extracted the characteristics of Indonesian PER topics and how those topics have been developed within the field over certain period.

Our novelty of the study clearly could be stated that we have recommended LDA algorithm because it has potential ability to break down great number of Indonesian PER literatures. It could extract the discovered Indonesian PER topics based on the nature of topics and their associated rise and fall within the field over certain period of time. This study then will be guided by two research questions in the following.

RQ1. Using LDA topic modeling on five Indonesian PER publications, what is the topic characteristics studied between 2014 and 2021 ?

RQ2. How has the development of these topics occured between 2014 and 2021?

2. Theoretical Review

Natural language processing (NLP) is the subfield of machine learning studies that performs topic modeling or text analysis from a set of documents. Broadly speaking, there are two types of machine learning (ML) models namely supervised and unsupervised algorithms. Supervised ML model creates a predetermined set of labels to fit, predict, or classify the trained dataset (documents). Conversely, unsupervised ML models do not specify the desired labels *a priori*. Hence, in unsupervised NLP, we do not have a predetermined set of results before processing the text analysis. They rather intend to extract latent entity from a set of documents without knowing the desired results previously. Thereafter, this technique actually may be troublesome to interpret the extracted topics due to the absence of predetermined labels. However, this limitation simultaneously often occured in common text analysis studies in which each researcher has to evaluate their interpretations to the extracted topics through several procedures explained in the subsequent methodological section of this paper.

Latent Dirichlet allocation (LDA) is one of the unsupervised NLP algorithms that has been commonly used in the topic modeling. Even though this text analysis technique has been limited with some simplifications as explained above, several fields have employed this method persuasively. After Blei et al. [19] published their LDA dissemination in 2003, LDA has been employed in several purposes such as analyzing the customer's opinion in agricultural companies [21], commercial reviews [22], political issues [23], and topics in online news portals [24]. Additionally, LDA also has been implemented in the educational environment to analyze informatics engineering studies [25], project report [26], undergraduate theses [27], scientific papers [28], and online educational resources [29,30]. Therefore, this numerous LDA implementations offer a promising tool in many fields even PER obviously. Recently, the LDA method has actually been implemented in the areas of PER [11] in analyzing 1302 individual papers from physics education research conference proceedings (PERC). However, this result is intended to cover the international nature of the dataset that was slightly less representative to grasp full knowledge about the development of Indonesian PER studies. To enrich the insight of Indonesian PER development, we believe that implication of our study should be worthwhile that is addressed merely on Indonesian PER publications.

Broadly speaking, LDA is a generative probabilistic model to analyze the latent topics from a set of documents. The document is presented as a collection of latent topics and

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

each topic is a collection of representative words. The aim of LDA is to identify the latent "topics" from a set of documents by counting the occurence of words in each document. It then should decide the amount of distinctive topics (K) based on a numeric measure, coherence score (α), about how well these topics "hang together" to represent the topics of the analyzed literature. After the representative model has been trained through the iterative processes to find the optimum consideration of coherence score (α), LDA will classify the representative words in each topic and the distribution of those topics in each document. Eventually, we are able to interpret these distinctive groups of words to differentiate one topic from another. According to this collection of words in each topic, we then can enumerate the term for each topic.

Mathematically, there are two matrices as an input and output of the LDA algorithm. The entry of each matrix represents the probability of co-occurrence, as illustrated in Figure 1. The input matrix corresponds to the documents row (D) and the words column (N) across the entire dataset (dimension $D \times N$, D is the amount of document and N is the amount of word), termed as *document–word matrix*. Each entry in the *document–word matrix* represents the probability of word mentioned in each document. This input matrix will be processed by LDA algorithm to create two output matrices. They are θ_D as *document–topic matrix* and β_K as *topic–word matrix* (Figure 1) that distribute the previous *document–word matrix* using a set of topics ($T_{1:K}$). The *document–topic matrix* (θ_D) corresponds to the document rows (D) and topic columns (K) (size $D \times K$, D is the amount of document and K is the amount of topic). The entries of θ_D represent the probability of a particular topic in a single document. The *topic–word matrix* (β_K) corresponds to the topic rows (K) and word columns (N) (size $K \times N$, K is the amount of topic and N is the amount of word). The entries of β_K demonstrate the probability of representative word in each latent topic. The interpretation of LDA algorithm through this view is known as probabilistic matrix factorization by Hoffman et al [31].

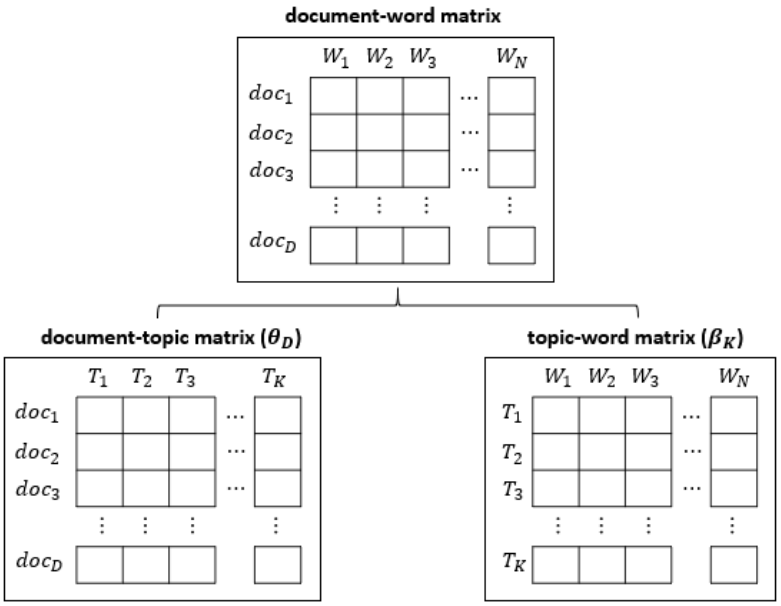

Figure 1. LDA interpretation through probabilistic matrix factorization

Based on the probabilistic matrix factorization, LDA rests on several assumptions that might be taken into account by the user. The first assumption is that LDA does not consider the word order in the text analysis so it specifically disregards "the nuance of language". Instead, it merely counts the number of mentioned words in each document. Actually, this is commonly assumed in many text analysis studies despite this major assumption. The first principle of text analysis proposed by Grimmer & Stewart [16] is also in line with aforementioned limitations. They stated that "all quantitative models of language are wrong, but some are useful".

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

The second assumption of LDA is that all documents should contain a mixture of several topics. Specifically, LDA believes in a mixed membership model of topic, rather than a single model of topic in each document. Contrarily, we believe that this second assumption then should lead to the valuable impact of LDA model in performing text analysis from the interdisciplinary nature like PER studies. It typically investigates specific research problems. They often bring, share, and combine insights, theories, or methods from another related field.

The last assumption of LDA believes that the representative words to a particular topic will be mentioned more often than another word in the documents. Then, the high probability of a particular word in a topic means that that word will tend to be co-occurred more frequently in a topic. This assumption is known as the distributional hypothesis of linguistics [17]. For instance, if the identified topic of a document is "culinary recipes", the words like "food", "ingredient", "taste", or "cook" will be likely to be co-occurred more frequent and used more often than the words "representation", "mechanics", "item", or even "conceptual understanding".

3. Method

Our study involved three common steps of LDA topic modeling, as demonstrated in Figure 2. In the following passages, we explain the details of stages in a consecutive way.

Figure 2. Illustrative diagrams of the study : (a) collecting and preprocessing the data; (b) modeling the topics through coherence parameter evaluation; (c) analyzing the results

3.1 Collecting and preprocessing the data

In this step, we started to collect the raw data sources by downloading the open-access based articles from five international conference proceedings published by ICRIEMS (N = 152) [32–41], ISSE (N = 220) [42–48], ICMSE (N = 125) [49–56], ICMScE (N = 291) [57–63], and ICoMSE [64–67] (N = 64) between 2014 and 2021. Collectively, our dataset was sourced from 852 documents (~ 4 to 8 pages each). We included all papers both from scopus indexed proceedings (Journal of Physics: Conference Series IOP Publishing, AIP Conference Proceedings, and Advances in Social Science, Education and Humanities Research Atlantis Press) and web based repository of each conference. We believe that those larger dataset would capture better representation of the published papers within the Indonesian PER community. Those conferences had multidisciplinary topics on other STEM discipline based education research thus we should ensure the downloaded file in accordance with the physics education research scope only. The definition of physics education research was determined based on the previous thematic analysis [9,11].

We decided to analyze those conference proceedings since they had been leading among the Indonesian TEIs in organizing international conferences particularly on the Indonesian PER field. Furthermore, the authors of those conferences were affiliated to several Indonesian higher institutions, various research experiences (graduate students to PER experts), and even attracted neighboring Southeast Asian countries. Therefore, those publications might be able to represent topics studied on Indonesian PER field and the development of those topics over certain period. Moreover, the authors of those publications came from outside of the organizing committees so it could represent the snapshot of both public and private Indonesian universities from several regions of Indonesia. Additionally, those articles had also been peer reviewed through several processes until the accepted decision was approved by the committee of publication. This might surpass the eligible standards for publications within Indonesian PER community.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

After the articles had been downloaded, we extracted the entire PDFs into a collection of words in each document using "pdfminer" library on python programming language. Then, we followed steps of data cleaning processes through "nltk" library [68] that were admittedly time-consuming steps in common text analysis study [69] (Figure 2.a). First, we checked the downloaded file to ensure that they were in well condition to be scraped into plain text. Second, we removed the section headers ('Abstract', 'Keywords', 'Figure', 'Introduction', 'Table', 'Method', 'Conclusion'), author's name, affiliation, reference, and acknowledgement section (if any) from the individual PDFs. Third, we took down the numbers, symbols, punctuations, and stop words based on the English vocabulary. Finally, the processed text would be tokenized into list of individual words in each document as our document-word matrix (see Figure 2.a).

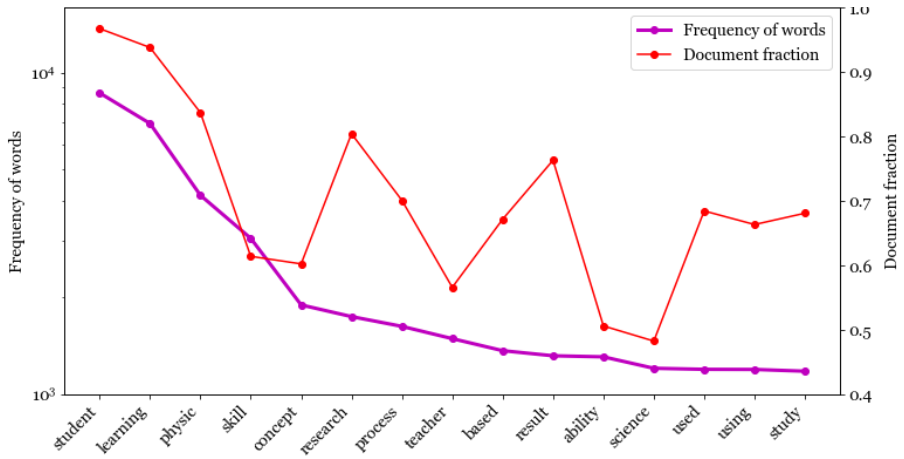

Figure 3. Distribution of words co-occurrence before the filtering process. Left axis represent words frequency and document fraction in the right axis visualized

After that, we employed "gensim" library [70] for the following data preprocessing. We lemmatized our list of tokens formerly. Lemmatization is the procedure to find the stem of some words that have the same essential meaning. Then, we searched pairs of words that were frequently mentioned together in the body of literature, they are called as bigrams such as "conceptual understanding", "problem solving" "scientific approach", "critical thinking", and so on. Bigrams should be combined together by inserting an underscore connecting the tokens. Finally, this step resulted "bag of words" contained 199578 raw words and bigrams with 10109 unique words. The tenth most frequent words in this data corpus are illustrated in Figure 3 above with associated words frequency and their fraction in each document (division between frequency and total of documents). The top 5 words that often co-occured through our dataset were "student", "learning", "physic", "skill", and "concept". Figure 3 illustrated the distribution of those frequent words. These frequent words should be entered in the next filtering step to ensure more efficient computing time and easier interpretation to the extracted PER topics.

Before we processed the bag of words into the LDA model, it should follow the filtering processes. Frequent words in Figure 3 makes our topics are difficult to be identified. Thus, the following step of LDA modeling was removing the most frequent words and the rarest words that were co-occurred in the bag of words. This removal action should be substantially noticed because the most mentioned words might obscure the topic characteristic studied among the literatures. Our emergent topics should be concerned to the most specific words rather than the most frequent words. Removing the rarest co-occuring words would also make our dataset more efficient. The larger size of data corpus with many noises will burdensome the running of the LDA algorithm hence the processing time might be inefficient. Several selection of this filtering parameters should be evaluated to achieve the optimum coherence parameter (α). This iterative process should be repeated ensuring the most representative topics with the optimum α.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

The selection of no above 55% filtering parameter to the frequent words has been determined through several evaluation processes based on the optimum coherence parameter α. The threshold of no below 15 times to the rarest words was also determined in the same way with the most frequent words. It eliminated substantive number of unique words and bigrams about 7724 words resulting the cleaned data as many as 2385 total words and bigrams (Figure 4). This was actually a huge amount of words however they do not contribute more to the specific description of a topic [71]. Moreover, as explained above, this filtering process will make the computing time on LDA algorithm more efficient since it will diminish the dimension of the LDA matrices mathematically. The second step of filtering processes decreased the total words in our dataset from 10109 to 2385 unique words and bigrams (see Figure 4). These representative words would determine the number of clustered topics in the Indonesian PER field which were evaluated by relative mixtures of topics (α) and face validity from PER experts.

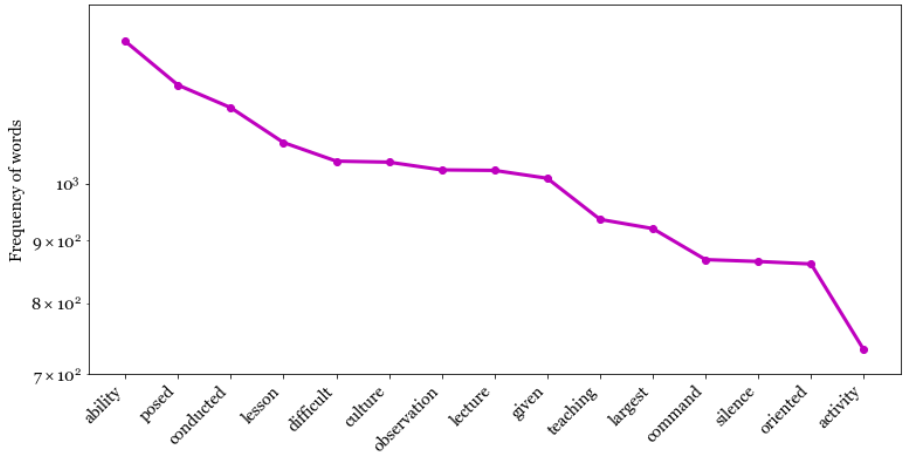

Figure 4. Distribution of words co-occurrence after the filtering process.

3.2 Modeling the topics through LDA and evaluating the results

After the cleaned dataset has been served, we maintained it using "pickle" format. During the iterative LDA modeling to the data, the unsupervised manner of LDA requires one needs several procedures of evaluation process in order to confirm the final results. Users have to ensure that their results make sense and do not deviate significantly based on the story of the research practice in the field. Practically, users often implement one or multiple methods of evaluation to examine the LDA results [16,72,73]. Several literatures have described some possible methods of evaluation in the following.

3.3.1 Coherence of descriptors in identified topics

Essentially, coherence value (α) is defined as a parameter how mixes the descriptors, the most frequent representative words, in each topic. In other words, this parameter measures whether these descriptors in each topic have supported each other to describe the topics or not. Basically, this is recommended by the distributional hypothesis of linguistics which believes that there must be some central words in a distinctive topic. The different set of words will be occured in a single topic than another topic [17,72]. The coherence value (α) will be normalized between 0 and 1. The descriptor of topics is "more coherent" when α is more higher and near to unity [74]. The best value of coherence will determine the final number of topics that will be concluded in the results.

One of the hyperparameters that should be tuned during the LDA modeling was number of topics (K). In this step, we build several LDA model with different number of topics (K). Higher coherence value (α) represented the more blended topics that we extracted from the LDA model. Figure 5 informed us that eight topics should be the best choice within our data corpus. The coherence value between 0.4 – 0.6 has been recommended by the previous study [11,18] as sufficient measure to interpret the results.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

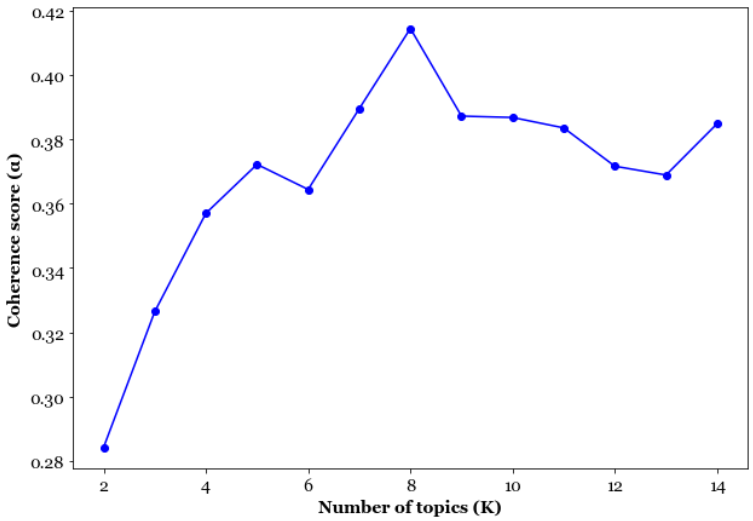

Figure 5. Coherence score (α) suggested eight topics for Indonesian PER literatures

3.3.2 Checking the face validity to PER experts

Face validity is a procedure to qualitatively evaluate the identified topics to the PER experts that are familiar with the PER publications and their state of the PER results. This will make sure the representativeness of our results based on their knowledge and experience [75]. More technically, evaluation of face validity requires expert who is familiar with the analyzed publication of the field in order to judge how coherent the topics based on their expertise, knowledge, and experience in the PER field [72]. The second author of this paper is a professor on Indonesian PER field with more than 20 years of research and teaching experiences, particularly at educational measurement on physics learning. The third author of this paper is an associate professor on electrical engineering that has more than 20 years of research and teaching experiences and have recent interest on artificial intelligence studies. These two authors has contributed to review the interpretation of extracted topics that have been made by the rest of authors. The second author was expected to enforce the PER aspect and the third author to ensure our LDA algorithm to extract the PER topics and their interpretation.

This study considered these two choices of several evaluation methods from the literature. Actually, there are other approaches such as perplexity of topic models and comparison with qualitative analysis to validate the LDA results. However, Chang et al. [76] reported that these techniques exhibit some limitations in their evaluations. To that reason, we left them as our evaluation procedures in this study.

3.3 Answering the research questions following the results of LDA model

After the LDA model has been trained to the most optimum coherence value (α), it will show the analysis results derived from the data corpus that has been derived from the previous bag of words. This modeling result (see the next section) was then interpreted either to answer the proposed research question of the study or to evaluate the optimum model. As the number of distinctive Indonesian PER topics has been classified, we then perform some determinations to find the most influential papers in each topic. This analysis was necessary to obtain the empirical face validity in the extracted topics and to define the description of every single topic. Thereafter, the terminology of each topic might be decided according to these considerations.

The development of each topic over certain period was measured by "prevalence" parameter research. In this study, prevalence was defined as the percentage of each topic in each year within the annual documents [11]. One topic in a high prevalence may be widely studied in certain years but fewer researched in other years. Eventually, it will illustrate the long shifts of Indonesian PER studies that have been attempted and visualize the room of future studies that could be addressed in the next efforts.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

4. Results

4.1 Indonesian PER topics and their representative papers (RQ1)

Trained LDA model was employed to produce eight different PER topics that is interpreted in Table 1 with their respective set of words and weights as our baseline to interpret the results. As a procedure of interpretation, we should initially notice their representative words and weights in each topic number. To that reason, we made our Table 1 is read from left to produce our interpretation in the right column (topic name). Our topic weights were representation of each word in each topic. Our findings reported spectrum of topic weights between 8% and 5.3% that was also reported as acceptable findings by the previous studies [11,18]. The order of topic number is arranged based on this weights that represents how blended the topic is within literatures.

Table 1. Characteristic of Indonesian PER topics

Topic number	Top 10 representative word	Weight	Topic name
1	critical_thinking	0.053	21st century skill
	st_century	0.025	
	ability	0.020	
	creative_thinking	0.016	
	information	0.014	
	technology	0.012	
	data	0.011	
	communication	0.011	
	creativity	0.010	
	need	0.008	
2	test	0.053	Assessment
	assessment	0.036	
	instrument	0.032	
	item	0.019	
	level	0.017	
	question	0.014	
	ability	0.013	
	measure	0.012	
	development	0.009	
	analysis	0.008	
3	science	0.034	Science literacy
	education	0.019	
	scientific_literacy	0.015	
	thinking_skill	0.013	
	thinking	0.012	
	ability	0.012	
	school	0.012	
	knowledge	0.012	
	scientific	0.010	
	level	0.009	
4	misconception	0.031	Conceptual understanding
	understanding	0.030	
	representation	0.017	
	conception	0.010	
	conceptual_understanding	0.010	
	scientific	0.010	
	level	0.009	
	phenomenon	0.009	
	difficulty	0.009	
	science	0.008	
5	model	0.032	Research based instruction
	activity	0.021	
	science_process	0.018	
	inquiry	0.011	
	achievement	0.011	
	class	0.010	

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

Topic number	Top 10 representative word	Weight	Topic name
	science	0.010	
	learning_outcome	0.010	
	scientific	0.009	
	knowledge	0.008	
6	problem	0.035	Problem solving
	problem_solving	0.028	
	ability	0.023	
	knowledge	0.012	
	solve_problem	0.011	
	improve	0.010	
	understanding	0.010	
	problemsolving_skill	0.009	
	approach	0.009	
	model	0.009	
7	medium	0.037	Educational technology
	development	0.022	
	material	0.021	
	technology	0.017	
	use	0.016	
	education	0.010	
	online	0.009	
	school	0.008	
	teaching_material	0.008	
	module	0.008	
8	experiment	0.020	Physics laboratory
	course	0.013	
	laboratory	0.012	
	motion	0.010	
	method	0.010	
	experimental	0.009	
	tool	0.009	
	practicum	0.008	
	understanding	0.007	
	activity	0.007	

The greater weights represent the more mixed the topics should be. Nevertheless, instead of Table 1, we recommended that one has to interpret based on the representative papers that are described in Table 2. It was kind of troublesome because there is possibility of disconnected words of a topic in Table 1 (in case of small weights) and made the interpretation more tricky. In this Table 2, we provide prevalence that is quantitative measure of how mixed the paper is within certain topic. For example, prevalence as many as 0.812 of Supahar's paper [77] represented that it composed 87.5% of the assessment topic and the remaining value on the other mixture across all other topics.

After the presentation of these tables, we provide distinctive ways to differentiate every topic that considers our results from Table 1 and Table 2. This will justify our reason for how we interpret LDA results towards eight Indonesian PER topics.

Table 2. Representative articles, author, year, respective conference, and prevalence in each Indonesian PER topics

Topic	Article	Author	Year	Conference	Prevalence
21st century skill	Profile of students' critical thinking ability in project based learning integrated science technology engineering and mathematics	Eja, Ramalis, & Suwarma	2019	ICMScE	0.812
	Gender differences in digital literacy among prospective physics teachers	Rizal, et al.	2020	ICMScE	0.799
	Profile of senior high school in-service physics teachers' technological pedagogical and content knowledge (TPACK)	Masrifah, et al.	2018	ICRIEMS	0.776
	Developing creative thinking skills of STKIP weetebula students through physics crossword	Anggraeni & Sole	2019	ICMScE	0.771

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

Topic	Article	Author	Year	Conference	Prevalence
	puzzle learning media using eclipse crossword app				
	Evaluation of critical thinking skills of class x high school students on the material of Newton's laws	Febriana & Sinaga	2020	ICMScE	0.759
Assessment	Applying content validity ratios (CVR) to the quantitative content validity of physics learning achievement tests	Supahar	2015	ICRIEMS	0.875
	An eight-category partial credit model as very appropriate for four-tier diagnostic test scoring in physics learning	Istiyono, et al.	2021	ISSE	0.873
	Developing of Bloomian HOTS Physics Test: Content and Construct Validation of The PhysTeBloHOTS	Istiyono & Dwandaru	2019	ICRIEMS	0.866
	Instrument test physics based computer adaptive test to meet the asian economic community literature review	Ermansah	2016	ISSE	0.861
	Implementation of Item Response Theory at Final Exam Test in Physics Learning: Rasch Model Study	Asriadi & Hadi	2020	ISSE	0.858
Science literacy	Mapping of professional, pedagogical, social, and personal competence of senior high school physics teachers in yogyakarta special region	Jumadi, Prasetyo, & Wilujeng	2014	ICRIEMS	0.772
	Analysis of Scientific Literacy Through PISA 2015 Framework	Arsyad, Sopandi, & Chandra	2016	ICMScE	0.766
	Shifting attitude from receiving to characterisation as an interdisciplinary learning toward ecological phenomena	Napitupulu, et al.	2017	ISSE	0.735
	Promoting metacognition and students' care attitude towards the environment through learning physics with STEM	Rahzianta & Purnama	2016	ISSE	0.708
	Analysis of senior high school students' higher order thinking skills in physics learning	Maulita, Sukarmin, & Marzuki	2018	ICRIEMS	0.690
Conceptual understanding	Alternative conception of high school students related to the concepts in the simple electric circuit subject matter	Wardiyah, Suhandi, & Samsudin	2018	ICMScE	0.879
	Identification of student misconception about static fluid	Setiawan, Saputra, & Rusdiana	2018	ICMScE	0.874
	External representation to overcome misconception in physics	Handhika, et al.	2015	ICMSE	0.870
	Teachers, pre-service teachers, and students understanding about the heat conduction	Anam, Widodo, & Sopandi	2018	ICMScE	0.869
	Identify students' conception and level of representations using five-tier test on wave concepts	Wiyantara, Widodo, & Prima	2020	ICMScE	0.849
Research based instruction	The effectiveness of local culture-based physics model of teaching in developing physics competence and national character	Suastra	2015	ICRIEMS	0.846
	Cooperative learning model design based on collaborative game-based learning approach as a soft scaffolding strategy: preliminary research	Nurulsari, Suyatna, Abdurrahman	2016	ICMScE	0.783
	Effect of free inquiry models to learning achievement and character of student class XI	Kaleka	2018	ICRIEMS	0.773
	Training students' science process skills through didactic design on work and energi	Ramayanti, Utari, & Saepuzaman	2017	ICMScE	0.769
	The effects of cooperative learning model think pair share assisted by animation media on learning outcomes of physics in high school	Astra, Susanti, & Sakinah	2019	ICMScE	0.765

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

Topic	Article	Author	Year	Conference	Prevalence
Problem solving	The effect of e-learning based worksheet to improve problem solving ability of senior high school students	Septiyono, Prasetyo, & Ihwan	2020	ISSE	0.812
	The analysis of students' problem-solving ability in the 5e learning cycle with formative e-assessment	Yuliana, et al.	2019	ICoMSE	0.797
	The development of physics e-book based on contextual teaching and learning to increase student problem-solving skill	Fitriadi, Latumalukita, & Warsono	2021	ISSE	0.791
	Improving students' problem-solving skills through quick on the draw model assisted by the optical learning book integrated the Pancasila	Himawan & Wilujeng	2019	ISSE	0.785
	Profile of problem solving ability of islamic senior high school students on momentum and impuls	Sakti, Wilujeng, & Alfianti	2021	ISSE	0.766
Educational technology	Developing whiteboard animation video through local wisdom on work and energy materials as physics learning solutions during the covid-19 pandemic	Anggraini, et al.	2020	ISSE	0.874
	Android-based carrom game comics integrated with discovery learning for physics teaching	Rahayu, Kuswanto, & Pranowo	2020	ICRIEMS	0.864
	Development of physics mobile learning media in optical instruments for senior high school student using android studio	Aji, et al.	2019	ISSE	0.843
	Smartphone-based learning media on microscope topic for high school students	Nadhiroh, et al.	2020	ISSE	0.831
	Android for the 21st century learning media and its impact on students	Adi, et al.	2016	ISSE	0.825
Physics laboratory	Simple vertical upward motion experiment using smartphone based phyphox app for physics learning	Janah, Ishafit, & Dwandaru	2021	ISSE	0.865
	The Atwood machine experiment assisted by smartphone acceleration sensor for enhancing classical mechanics experiments	Listiaji, Darmawan, & Dahnuss	2020	ICMSE	0.853
	Development of sound wave experimentation tools influenced by wind velocity	Maisyaroh, et al	2019	ISSE	0.840
	Analysis of simple harmonic spring motion using tracker software	Mu'iz, et al.	2017	ICMScE	0.827
	Real laboratory based learning using video tracker on terminal velocity	Ristanto, Novita, & Saptaningrum	2016	ISSE	0.824

4.1.1. Topic 1 : 21st century skill

This topic is the most mixed cluster based on the sorted list through descending weight measures. Promoting 21st century skill is the main concern from papers published within this topic cluster. Keywords including "critical_thinking", "creative_thinking", and "communication" are several main components that are expected (refers to "need") to support the well known four components of 21st century learning skills (4Cs) [78]. Additionally, the emergence of digital technology in the recent era encourages our physics educators to approach their physics learning to digital platforms including "information", "data", and "technology". This topic could be stated as the most influential party and takes many attentions in the basis of Indonesian PER literature recently.

4.1.2. Topic 2 : Assessment

This topic focuses on developing measurement tool that was needed in performing and evaluating research based instructions within PER community. It was composed of several representative words to represent how we develop measurement tool including "test", "instrument", "item", "question", and "measure". These tools were expected to quantify physics education related "ability" in physics classrooms. Moreover, several modern measurement theories including item response theory and rasch analysis were

 doi:10.20944/preprints202208.0198.v1

mainly concerned by Indonesian PER members within this topic. The emergent "level" keyword was related to the other topics particularly science literacy and conceptual understanding below. It could represent several assessment concerns to factors that were mainly highlighted on students' performance within Indonesian PER community.

4.1.3. Topic 3 : Science literacy

Instead of 21st century skills that are focused in the first topic formerly, this topic underlines other form of students' performance in terms of science literacy (refers to keywords "scientific_literacy", "knowledge", "scientific"). Research movements on science literacy might be collectively guided by the national results of Programme for International Student Assessment (PISA) assessment for Indonesian secondary students [79]. PER members are one of discipline based education research (DBER) on STEM education (refers to keywords "science", "education", "school") that is responsible for this duty call in improving students' performance on scientific literacy. In addition to the focus of this topic, the keyword of "thinking_skill" was particularly relevant to "higher_order" in the eleventh rank of representative words in this topic, nevertheless, it could not be shown in the Table 1. Higher order thinking skills (HOTS) was also considered as other students' performance that is correlated with other factors including scientific literacy and aforementioned 21st century learning skills [80,81].

4.1.4. Topic 4 : Conceptual understanding

This topic is relevant with the previous result by Docktor and Mestre's [9] synthesis results towards research articles on PER literature for several decades. The earliest movement of PER literatures underlined this concern that is fundamental for physics learning. Conceptual understanding could be concluded in this category because there are several keywords including "misconception", "understanding", "conception". In addition to conceptual understanding, "representation" on physics understanding is also relevant on conceptual physics understanding [9,11]. Odden et al [11] even discovered this in their thematic analysis results with the same methodology of the current study. "Difficulty" on conceptual understanding is also studied in this topic category.

4.1.5. Topic 5 : Research based instruction

In addressing improvement of students' performance (refers to "achievement", "knowledge") on physics learning, several learning transformations (refer to "model", "activity") have been attempted by PER members. Due to the national call on 2013 curriculum, Indonesian physics education was encouraged to approach science process skill as five cycles of learning pace. It was termed as "5M" for Indonesian language [82] and translated as inquiry based learning in several general literatures. This movement made it logical if our several empirical literatures mentioned keywords including "science_process" and "inquiry" in this topic.

4.1.6. Topic 6 : Problem solving

Relevant to the fourth topic formerly, this current topic was also reported by previous study from Docktor and Mestre's [9] synthesis analysis. Problem solving skill (several termed as ability) is fundamental factor to be successful physics learner. Content knowledge on physics is primarily discovered through critical problem solving steps to understand how our physical circumstance works. Moreover, several terms including "improve", "approach", and "model" represent that Indonesian PER scholars translate it as learning strategy to endorse this imperative topic.

4.1.7. Topic 7 : Educational technology

Keyword "medium" in this topic was lemmatized from "media" that was frequently mentioned in several papers about developing learning material (refers to keyword "material", "module", "teaching material") through technology enhanced learning (refers to "technology", "online") that is implemented on physics lesson.

4.1.8. Topic 8 : Physics laboratory

"Experimental" physics is considered as one way of physics knowledge that might be approached to be immersed as a physics person. This topic focuses on how physics

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

learning or "course" was delivered through real or virtual "laboratory" in conducting the "practicum activity". Several papers also developed physical measurement "tool" that could be employed to enhance students' experience in the physics laboratory. Eventually, through this channel, PER studies also consider addressing their learning treatment to improve "understanding" on physics. The appearance of keyword "motion" in this topic represents a physics topic that is mostly addressed is Newtonian mechanics.

4.2 Development of Indonesian PER topics between 2014 and 2021 (RQ2)

In the second research question, we investigated the development of Indonesian PER topics through the measure of topic prevalence between 2014 and 2021. We employ the definition of prevalence that has been approached by previous study of Odden, et al. [11]. Prevalence of a particular topic is defined as the sum of documents that is categorized about a particular topic in a certain year. This measure is represented as percentage that could be aggregated both cumulatively (Figure 6) and averaged (Figure 7) by year. For instance, 10% prevalence of topic 1 in a certain year has two fold representation. First, it represents the average prevalence of topic 1 for that year as many as 10%. Then, the cumulative prevalence of topic 1 for that year as many as 10%×N, in which N is the amount of documents published in that year. If the annual cumulative prevalence of all topics are summed up then it would correspond to the total of documents published in that year.

Cumulative prevalence of eight identified topics between 2014 and 2021 are illustrated in Figure 6. Cumulative prevalence of a topic in the y axis is provided as the number of "effective" papers disseminated in that year. For example, 25 cumulative prevalences of 21 st century skill topic in 2018 (see Figure 6) means that there is equivalent as 25 "effective" articles addressed about 21 st century skill in that year. This term of "effective" is inspired by the previous research [11] because, as a reminder, LDA results are underlaid the mixed membership of topics. An individual article should be categorized in several topics (in varying weights) rather than a single topic.

We provide shaded areas in Figure 6 to describe topical distribution for annual topic development. The width of shaded area in Figure 6 is the standard deviation (σ). We used as many as 3σ from the mean value that is represented by the solid line in Figure 6. We calculated this standard deviation using the jackknife resampling technique [83]. For certain topics and years, this procedure yielded a new sample of 100 cumulative prevalence values. Standard deviation that is calculated to describe the distribution of a topic prevalence in each year is calculated using this new sample.

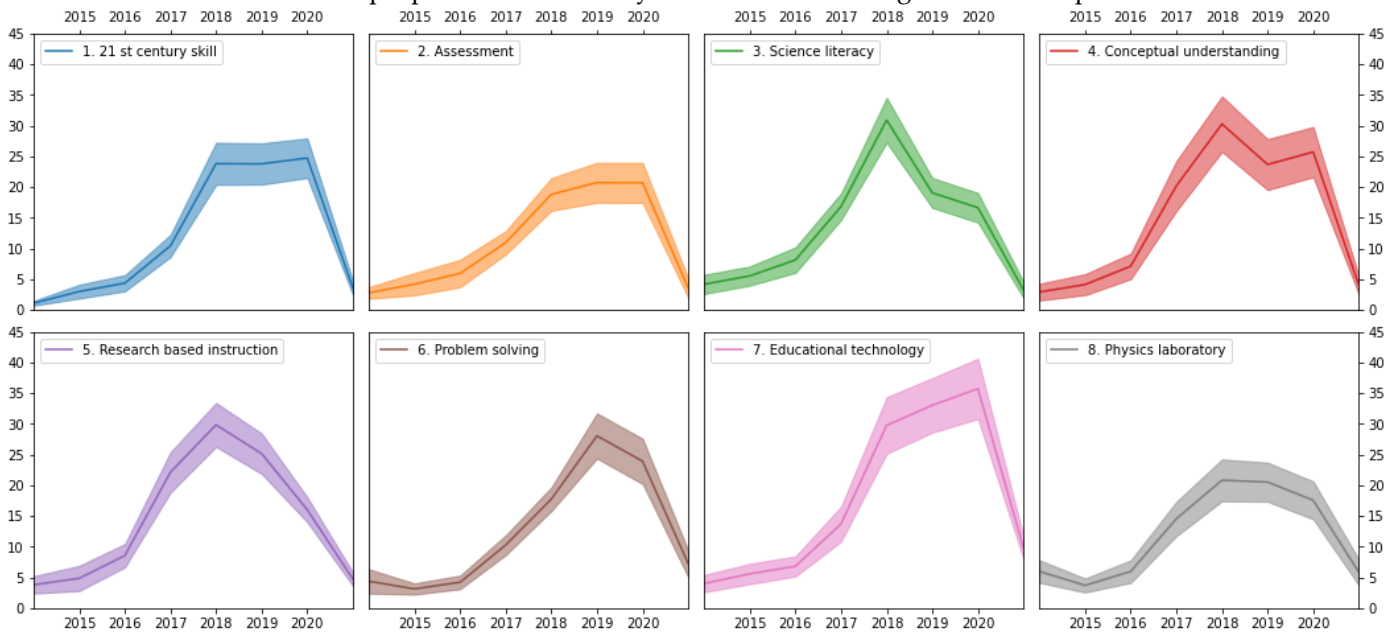

Figure 6. Cumulative prevalence of Indonesian PER topics development between 2014 and 2021

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 August 2022 doi:10.20944/preprints202208.0198.v1

The jackknife resampling method described above produces the shaded areas that could be represented as the topical variation for certain year. A shaded area of 0 during one year would be produced if there is no difference among cumulative prevalence of several topics during a single year. On the other hand, if there is several papers that are focused heavily on certain topic, the shaded area (topical spread) would be larger.

Figure 6 illustrates that all of our topics have exhibited similar rise and fall between 2014 and 2021 relatively. There is spike about 2018 and 2019 and the following decrease at the subsequent year for all of the topics. We suspect that apparent decrease is because several publications in the year of 2021 are still progressing. Broadly speaking, disruptive transition during the 2020 pandemic year has tremendously influenced the attendance of potential PER researchers from several parts of Indonesian institutions [84]. Moreover, our dataset of 2021 conference is merely sourced from the ISSE conference and the rest of conferences are still progressing through publication processes. Figure 6 describes the lowest cumulative topic prevalence occured in the early year of 2014. The finding is actually not surprising because there is only two conferences that have been organized by UNY (through ICRIEMS) and UNNES (through ICMSE) in that year. Measure of cumulative topic prevalence is particularly dependent on the number of documents written for particular year. There are stable cumulative prevalences particularly on 21st century skill and assessment topic even the assessment topic has the lower prevalence. Educational technology has the highest increased prevalence in the more recent years. There are similar spikes described by science literacy and conceptual understanding topic in 2018. However, for the following year science literacy has more substantial decrease than conceptual understanding topic. Problem solving topic has the latest spike in 2019. Unfortunately, physics laboratory seemed to be minority within Indonesian PER community due to the smallest topic prevalence among other Indonesian PER topics.

As described above, cumulative measure of topic prevalence is merely depend on the number of "effective" documents published in that year. Hence, we need average measure that could be fairly interpreted to compare different topics through year to year. In this study, we have calculated data-smoothing technique which dampens out the effect of sample dependence in the year to year variation. Three rolling windows averaged the prevalence values for each year with those of the former and subsequent year. Figure 7 depicts our plot of average Indonesian PER topics prevalence over time.

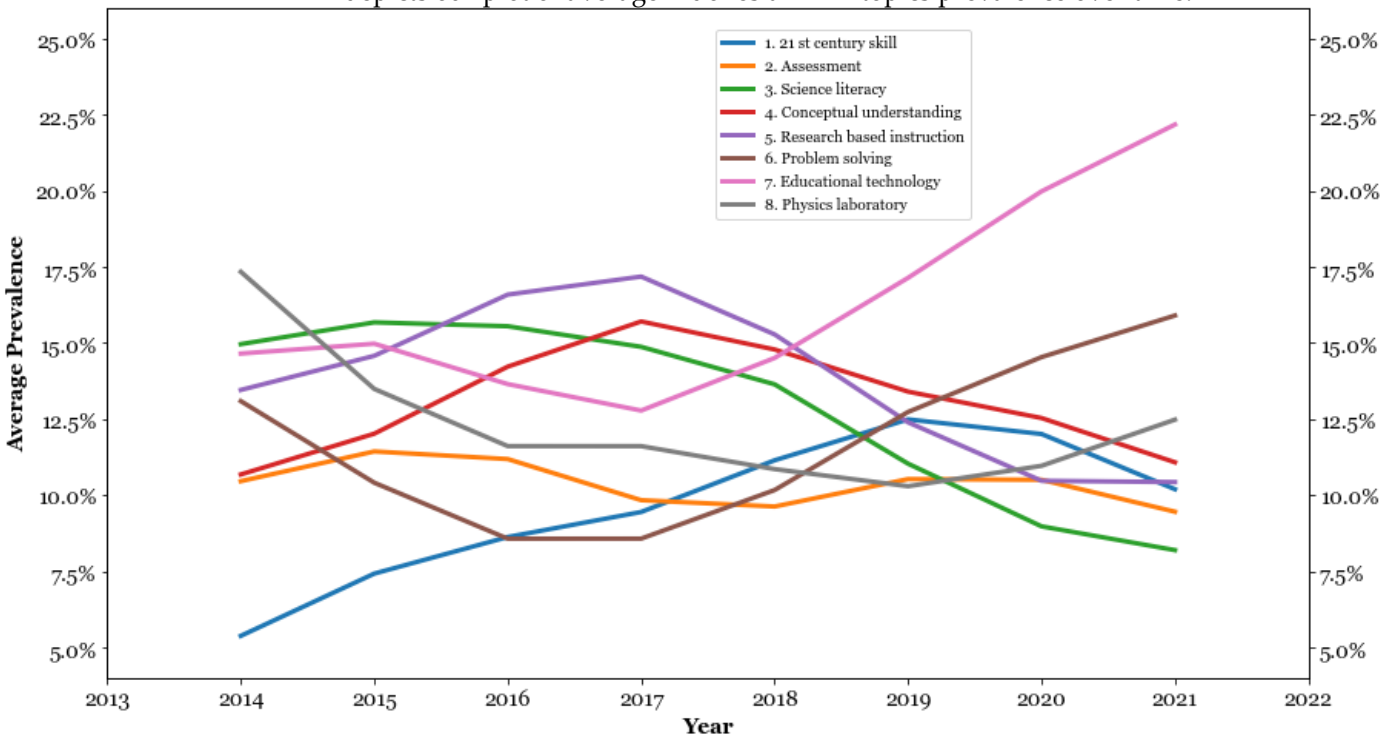

Figure 7. Average prevalence of Indonesian PER topics development between 2014 and 2021

 doi:10.20944/preprints202208.0198.v1

Based on the average prevalence visualization in Figure 7, there is relative stability of rise and fall for all of the topics between 2014 and 2018. The most interesting topics within literatures are interchanged throughout year to year. In the early of 2014, physics laboratory topic emerged to dominate the movements, however, this topic followed decreased pattern through several subsequent years after that. In the next year, science literacy has attracted our Indonesian PER scholars for their most attention within community. Moreover, there is continuous pattern that research based instruction topic led the waves between 2016 and 2018. Nevertheless, this topic has substantially decrease for the subsequent years and the position was overtaken by educational technology after 2018 and problem solving topic after 2019. We then notice that assessment topic remained fairly stable over time on average. It might indicate that this PER topic has been considered to be studied through collective development to support the promotion of 21st century skill and other students' performance including science literacy, conceptual understanding, and problem solving. In the early year, it is interesting that 21 st century skill even has the lowest attention in 2014. Although we cannot conclude for particular where this trend comes from. Looking at the representative papers within this topic (see Table 2), we argue that the lowest prevalence of 21st century skill in the early year of 2014 corresponded to the limited digital technology that has been approachable during this year. Eventually, this topic sustained to develop until 2019 subsequently. There is likely to become greater in following the associated trends of increased educational technology until 2021.

5. Discussion

For the answer of RQ1, we have extracted eight Indonesian PER topics using the LDA algorithm toward five publications on physics education research conferences organized by Indonesian PER members between 2014 and 2021. They are composed of (1) 21st century skill, (2) assessment, (3) science literacy, (4) conceptual understanding, (5) research based instruction, (6) problem solving, (7) educational technology, and (8) physics laboratory. The description to distinct each of these emergent topics has been provided through Table 1 and Table 2 above with several representative papers to emphasize one topic rather than another topic.

For the answer of RQ2, the development of Indonesian PER topics has dominated interchangeably in certain years (see Figure 6 and 7). Nevertheless, we admit that several topics recommend that their development appear fair and stable between 2014 and 2021. In the early year of our analysis period, Indonesian PER members put their attention more to study how physics learning should be immersed through physical laboratory. Over time, we discovered that it was overtaken by research based instruction in transforming prior physics learning into several reforms to approach several forms of students' performance. In more recent years, Indonesian PER field has been encouraged by the demand of digital technology enhanced learning that attracted Indonesian PER scholars to develop supplemental materials for physics instruction using various technological approaches. This was also relevant with the movement of problem solving topics during the time to promote the increasing trends on 21st century learning since 2014.

We could understand these current findings by comparing them to those previous works that have been published before. Table 3 summarizes PER themes that have been reported by Docktor and Mestre's study [9] and Odden et al. 's study [11]. Using more traditional large-scale synthesis analysis, Docktor and Mestre have extracted PER topics into six primary topical areas of physics education research. Using the same method as the current study, Odden et al. has extracted PER topics into ten research themes using 1304 papers for physics education research conference (PERC).

 doi:10.20944/preprints202208.0198.v1

Table 3. Previous works about thematic analysis of PER literatures

Docktor and Mestre [9]	Odden et al. [11]
1. Conceptual understanding	1. Representation
2. Problem solving	2. Problem solving
3. Curriculum and instruction	3. Labs
4. Assessment	4. Quantitative assessment of concept
5. Cognitive psychology	5. K-12
6. Attitudes and beliefs about teaching and learning	6. Difficulties with quantum mechanics
	7. Community, identity
	8. Qualitative methodology and constructivist theory building
	9. Research based instruction
	10. Quantitative survey of demographic gap

Comparing our topical findings to the previous works, there are several topics or terms that were overlapped. We have similar findings with Docktor and Mestre's review on conceptual understanding, problem solving, and assessment topics. There are three topics overlapped with Odden, et al's thematic analysis including problem solving, physics laboratory, and research based instruction. It is followed by three unique Indonesian PER topics that are missing from two previous studies including 21st century skill, science literacy, and educational technology. We argue that this immediate differences correspond to the different contexts according to the authors' point of view. If we review synthesis' results of Docktor and Mestre, those topics might be categorized in the context of assessment or curriculum and instruction. Educational technology that has been developed by Indonesian PER members was assumed as learning transformation within PER community summarized in Docktor and Mestre's curriculum and instruction theme. Moreover, 21st century skill and science literacy were other forms of students' performance considered in the assessment topic of Docktor and Mestre's results. Moreover, this unique pattern derived from Indonesian PER literatures could be understood as educational development within certain country might be determined through several social contexts and governmental policy [79,82,85,86].

For the open room of future project, we discovered Indonesian PER topics should address research focused on qualitative aspects of physics teaching and learning. Comparing to the Odden et al.'s thematic results, there were qualitative topics dealing with community and identity as well as qualitative methodology and constructivist theory building that were still missing within Indonesian PER literatures. This methodological approach is also relevant with Docktor and Mestre's result to investigate cognitive psychology and attitudes and beliefs about physics education. Those trends still lack of research within Indonesian PER literatures and there is possible room for future study within this topic.

One might realize that our findings could contribute to make recommendation for Indonesian PER community. Since, to the best of our knowledge, there is no similar research that has been attempted within community using LDA to break down the growing size of Indonesian PER literatures. Our paper should recommend several topics that has been published and future directions that should be approached in the next research project within community. Through our LDA results, Indonesian PER community could understand what valuable steps that have been attempted and where we would go for the future Indonesian PER community. Admittedly, there are several limitations in using LDA to analyze research literatures. We did not ignore that the results of this analysis may be interpreted as a different meaning in other places that accidentally did not publish their works in those conferences. The determination of five conferences that have been engaged through our analysis might be arguable position that has been chosen by the authors. In summary, other PER researchers could look forward to using the LDA method for future explorations of the larger Indonesian PER literatures.

6. Conclusions

In this paper, Indonesian PER literatures have been thematically analyzed using LDA algorithm. There are eight topics that have been approached by our PER members including 21st century skills, assessment, science literacy, conceptual understanding, research based instruction, problem solving, educational technology, and physics laboratory. In the early initiation of Indonesian PER conferences in 2014, our members put more attention on approaching learning through physics laboratory. They brought us to the movement in responding to the demand of 21st century learning experience within physics lessons. Our educators then were encouraged to harness several educational technologies in promoting other forms of students' performances on physics including science literacy and higher order thinking skill based on 21st century learning call.

Supplementary Materials: The python code of this thematic analysis can be downloaded at: https://github.com/santosoph/Indonesian-PER-thematic-analysis (accessed on 19 July 2022).

Author Contributions:

Funding: This research received no external funding.

Informed Consent Statement: Not applicable

Data Availability Statement: The cleaned data of this project (pickle format) and metadata of articles (excel format) can be downloaded at: https://github.com/santosoph/Indonesian-PER-thematic-analysis (accessed on 19 July 2022).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. FMIPA UNY International Conference on Research, Implementation, and Education of Mathematics and Science Available online: http://icriems.uny.ac.id/ (accessed on 9 July 2022).
2. FMIPA UNY International Seminar on Science Education Available online: http://isse.uny.ac.id/ (accessed on 9 July 2022).
3. FMIPA UNNES International Conference on Mathematics, Science, and Education Available online: https://icmseunnes.com/ (accessed on 9 July 2022).
4. FMIPA UPI International Conference on Mathematics and Science Education Available online: http://science.conference.upi.edu/icmsce2022/ (accessed on 9 July 2022).
5. FMIPA UM International Conference on Mathematics and Science Education Available online: http://icomse.fmipa.um.ac.id/ (accessed on 9 July 2022).
6. Choe, K.; Jung, S.; Park, S.; Hong, H.; Seo, J. Papers101: Supporting the Discovery Process in the Literature Review Workflow for Novice Researchers. *IEEE Pacific Visualization Symposium* **2021**, *2021-April*, 176–180, doi:10.1109/PACIFICVIS52677.2021.00037.
7. Ameen, K.; Batool, S.H.; Naveed, M.A. Difficulties Novice LIS Researchers Face While Formulating a Research Topic. *Information Development* **2019**, *35*, doi:10.1177/0266666918774875.
8. McDermott, L.C.; Redish, E.F. Resource Letter: PER-1: Physics Education Research. *American Journal of Physics* **1999**, doi:10.1119/1.19122.
9. Docktor, J.L.; Mestre, J.P. Synthesis of Discipline-Based Education Research in Physics. *Physical Review Special Topics - Physics Education Research* **2014**, doi:10.1103/PhysRevSTPER.10.020119.
10. Meltzer, D.E.; Otero, V.K. A Brief History of Physics Education in the United States. *American Journal of Physics* **2015**, doi:10.1119/1.4902397.
11. Odden, T.O.B.; Marin, A.; Caballero, M.D. Thematic Analysis of 18 Years of Physics Education Research Conference Proceedings Using Natural Language Processing. *Physical Review Physics Education Research* **2020**, doi:doi.org/10.1103/PhysRevPhysEducRes.16.010142.

12. Faisal; Gi, G.M.; Martin, S.N. Analysis of Government-Funded Research in Indonesia from 2014-2018: Implications for Research Trends in Science Education. *Jurnal Pendidikan IPA Indonesia* **2020**, doi:10.15294/jpii.v9i2.23174.
13. Ni'mah, F. Research Trends of Scientific Literacy in Indonesia: Where Are We? *Jurnal Inovasi Pendidikan IPA* **2019**, doi:10.21831/jipi.v5i1.20862.
14. Chusni, M.M.; Zakwandi, R. Trend Analysis of Physics Prospective Teachers' Research: An Efford to Improve The Academic Quality of Physics Study Program. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni* **2018**, doi:10.24042/jipfalbiruni.v7i1.2143.
15. Hari Kristiyanto, W.; Kardi, S. Trend of Research on Physics Learning Media and Its Findings. In Proceedings of the International Conference on Mathematics, Science, and Education; 2015.
16. Grimmer, J.; Stewart, B.M. Text as Data: The Promise and Pitfalls of Automatic Content Analysis Methods for Political Texts. *Political Analysis* **2013**, doi:10.1093/pan/mps028.
17. Harris, Z.S. Distributional Structure. *Word* **1954**, doi:10.1080/00437956.1954.11659520.
18. Odden, T.O.B.; Marin, A.; Rudolph, J.L. How Has Science Education Changed over the Last 100 Years? An Analysis Using Natural Language Processing. *Science Education* **2021**, *105*, doi:10.1002/sce.21623.
19. Blei, D.M.; Ng, A.Y.; Jordan, M.I. Latent Dirichlet Allocation. *Journal of Machine Learning Research* **2003**, doi:10.1016/b978-0-12-411519-4.00006-9.
20. Advances in Neural Information Processing Systems. *Advances in Neural Information Processing Systems* 2018.
21. Agustina, A.; Pradina, R. Analisis Dan Visualisasi Suara Pelanggan Pada Pusat Layanan Pelanggan Dengan Permodelan Topik Menggunakan Latent Dirichlet Allocation (LDA) Studi Kasus: PT. Petrokimia Gresik, 2017.
22. Nugroho, D.D.A.; Alamsyah, A. Analisis Konten Pelanggan Airbnb Pada Network Sosial Media Twitter. In Proceedings of the e-Proceeding of Management; 2018.
23. Hikmah, F.N.; Basuki, S.; Azhar, Y. Deteksi Topik Tentang Tokoh Publik Politik Menggunakan Latent Dirichlet Allocation (LDA). *Jurnal Repositor* **2020**, doi:10.22219/repositor.v2i4.52.
24. Prihatini, P.M.; Suryawan, I.K.; Mandia, I.N. Metode Latent Dirichlet Allocation Untuk Ekstraksi Topik Dokumen. *Jurnal Logic* **2017**.
25. Nurlayli, A.; Nasichuddin, Moch.A. Topik Modeling Penelitian Dosen Jptei Uny Pada Google Scholar Menggunakan Latent Dirichlet Allocation. *Elinvo (Electronics, Informatics, and Vocational Education)* **2019**, doi:10.21831/elinvo.v4i2.28254.
26. Setijohatmo, U.T.; Rachmat, S.; Susilawati, T.; Rahman, Y.; Kunci, K. Analisis Metoda Latent Dirichlet Allocation Untuk Klasifikasi Dokumen Laporan Tugas Akhir Berdasarkan Pemodelan Topik. *Prosiding The 11th Industrial Research Workshop and National Seminar* **2020**.
27. Alfanzar, A.I.; Khalid, K.; Rozas, I.S. Topic Modelling Skripsi Menggunakan Metode Latent Diriclhet Allocation. *JSiI (Jurnal Sistem Informasi)* **2020**, doi:10.30656/jsii.v7i1.2036.
28. Riduwan, M.; Fatichah, C.; Yuniarti, A. Klasterisasi Dokumen Menggunakan Weighted K-Means Berdasarkan Relevansi Topik. *JUTI: Jurnal Ilmiah Teknologi Informasi* **2019**, doi:10.12962/j24068535.v17i2.a892.
29. Arianto, B.W.; Anuraga, G. Topic Modeling for Twitter Users Regarding the "Ruanggguru" Application. *Jurnal Ilmu Dasar* **2020**, doi:10.19184/jid.v21i2.17112.
30. Wilson, J.; Pollard, B.; Aiken, J.M.; Caballero, M.D.; Lewandowski, H.J. Classification of Open-Ended Responses to a Research-Based Assessment Using Natural Language Processing. *Physical Review Physics Education Research* **2022**, *18*, 010141, doi:10.1103/PhysRevPhysEducRes.18.010141.
31. Hoffman, M.D.; Blei, D.M.; Bach, F. Online Learning for Latent Dirichlet Allocation. In Proceedings of the Advances in Neural Information Processing Systems 23: 24th Annual Conference on Neural Information Processing Systems 2010, NIPS 2010; 2010.

32. FMIPA UNY. Proceedings of the 1st International Conference on Research, Implementation, & Education of Mathematics and Science 2014 Available online: https://eprints.uny.ac.id/view/subjects/ICRIEMS.html (accessed on 9 July 2022).
33. FMIPA UNY. Proceedings of the 6th International Conference on Research, Implementation, & Education of Mathematics and Science 2019 Available online: http://seminar.uny.ac.id/icriems/proceeding2019 (accessed on 9 July 2022).
34. FMIPA UNY. Proceedings of the 5th International Conference on Research, Implementation, & Education of Mathematics and Science 2018 Available online: http://seminar.uny.ac.id/icriems/proceeding2018 (accessed on 9 July 2022).
35. FMIPA UNY. Proceedings of the 4th International Conference on Research, Implementation, & Education of Mathematics and Science 2017 Available online: http://seminar.uny.ac.id/icriems/proceedings2017 (accessed on 9 July 2022).
36. FMIPA UNY. Proceedings of the 3rd International Conference on Research, Implementation, & Education of Mathematics and Science 2016 Available online: http://seminar.uny.ac.id/icriems/proceedings2016 (accessed on 9 July 2022).
37. FMIPA UNY. Proceedings of the 2nd International Conference on Research, Implementation, & Education of Mathematics and Science 2015 Available online: https://eprints.uny.ac.id/view/subjects/icriems2015.html (accessed on 9 July 2022).
38. FMIPA UNY. Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences 2020 Available online: https://www.atlantis-press.com/proceedings/icriems-20 (accessed on 9 July 2022).
39. FMIPA UNY. Proceedings of the 6th International Conference on Research, Implementation, and Education of Mathematics and Science 2019. *Journal of Physics: Conference Series* **2019**, *1397*, doi:10.1088/1742-6596/1397/1/011001.
40. FMIPA UNY. Proceedings of the 5th International Conference on Research, Implementation, & Education of Mathematics and Science 2018. *Journal of Physics: Conference Series* **2018**, *1097*, doi:10.1088/1742-6596/1097/1/011001.
41. FMIPA UNY. Proceedings of the 4th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS). *AIP Conference Proceedings* **2017**, *1868*, doi:10.1063/1.4995086.
42. FMIPA UNY. Proceedings of the 8th International Seminar on Science Education 2022 Available online: http://isse.uny.ac.id/presenter-2021 (accessed on 9 July 2022).
43. FMIPA UNY. Proceedings of the 6th International Seminar on Science Education 2020 Available online: https://www.atlantis-press.com/proceedings/isse-20 (accessed on 9 July 2022).
44. FMIPA UNY. Proceedings of the 5th International Seminar on Science Education 2019. *Journal of Physics: Conference Series* **2020**, *1440*, doi:10.1088/1742-6596/1440/1/011001.
45. FMIPA UNY. Proceedings of the 4th International Seminar on Science Education 2018. *Journal of Physics: Conference Series* **2018**, *1233*, doi:10.1088/1742-6596/1233/1/011001.
46. FMIPA UNY. Proceedings of the 3rd International Seminar on Science Education 2017 Available online: http://seminar.uny.ac.id/isse2017/ (accessed on 9 July 2022).
47. FMIPA UNY. Proceedings of the 2nd International Seminar on Science Education 2016 Available online: http://seminar.uny.ac.id/isse2016/?q=home (accessed on 9 July 2022).
48. FMIPA UNY. Proceedings of the 1st International Seminar on Science Education 2015 Available online: http://seminar.uny.ac.id/isse2015/ (accessed on 9 July 2022).

49. FMIPA UNNES. Proceedings of the 7th International Conference on Mathematics and Science Education 2020 Available online: https://iopscience.iop.org/volume/1742-6596/1918 (accessed on 9 July 2022).
50. FMIPA UNNES. Proceedings of the 6th International Conference on Mathematics and Science Education 2019 Available online: https://iopscience.iop.org/volume/1742-6596/1567 (accessed on 9 July 2022).
51. FMIPA UNNES. Proceedings of the 5th International Conference on Mathematics and Science Education 2018 Available online: https://iopscience.iop.org/volume/1742-6596/1321 (accessed on 9 July 2022).
52. FMIPA UNNES. Proceedings of the 4th International Conference on Mathematics and Science Education 2017. *Journal of Physics: Conference Series* **2017**, *983*, doi:10.1088/1742-6596/983/1/011001.
53. FMIPA UNNES. Proceedings of the 3rd International Conference on Mathematics and Science Education 2016. *Journal of Physics: Conference Series* **2017**, *824*, doi:10.1088/1742-6596/824/1/011001.
54. FMIPA UNNES. Proceedings of the 3rd International Conference on Mathematics and Science Education 2016 Available online: https://icmseunnes.com/2016/ (accessed on 9 July 2022).
55. FMIPA UNNES. Proceedings of the 2nd International Conference on Mathematics and Science Education 2015 Available online: https://icmseunnes.com/2015/ (accessed on 9 July 2022).
56. FMIPA UNNES. Proceedings of the 1st International Conference on Mathematics and Science Education 2014 Available online: https://icmseunnes.com/2015/?page_id=336 (accessed on 9 July 2022).
57. FMIPA UPI. Proceedings of the 5th International Conference on Mathematics and Science Education 2020 Available online: http://science.conference.upi.edu/proceeding/index.php/ICMScE/issue/view/5 (accessed on 9 July 2022).
58. FMIPA UPI. Proceedings of the 4th International Conference on Mathematics and Science Education 2019 Available online: http://science.conference.upi.edu/proceeding/index.php/ICMScE/issue/view/4 (accessed on 9 July 2022).
59. FMIPA UPI. Proceedings of the 3rd International Conference on Mathematics and Science Education 2018 Available online: http://science.conference.upi.edu/proceeding/index.php/ICMScE/issue/view/3 (accessed on 9 July 2022).
60. FMIPA UPI. Proceedings of the 5th International Conference on Mathematics and Science Education 2020. *Journal of Physics: Conference Series* **2020**, *1806*, doi:10.1088/1742-6596/1806/1/011001.
61. FMIPA UPI. Proceedings of the 4th International Conference on Mathematics and Science Education 2019 Available online: https://iopscience.iop.org/volume/1742-6596/1521 (accessed on 9 July 2022).
62. FMIPA UPI. Proceedings of the 3rd International Conference on Mathematics and Science Education 2018 Available online: https://iopscience.iop.org/volume/1742-6596/1157 (accessed on 9 July 2022).
63. FMIPA UPI. Proceedings of the 2nd International Conference on Mathematics and Science Education 2017. *Journal of Physics: Conference Series* **2017**, *895*, doi:10.1088/1742-6596/895/1/011001.
64. FMIPA UM. Proceedings of the 4th International Conference on Mathematics and Science Education 2020. *AIP Conference Proceedings* **2020**, *2330*, doi:10.1063/12.0003318.
65. FMIPA UM. Proceedings of the 3rd International Conference on Mathematics and Science Education 2019. *AIP Conference Proceedings* **2019**, *2215*, doi:10.1063/12.0000206.
66. FMIPA UM. Proceedings of the 2nd International Conference on Mathematics and Science Education 2018. *Journal of Physics: Conference Series* **2018**, *1227*, doi:10.1088/1742-6596/1227/1/011001.
67. FMIPA UM. Proceedings of the 1st International Conference on Mathematics and Science Education 2017. *Journal of Physics: Conference Series* **2018**, *1093*, doi:10.1088/1742-6596/1093/1/011001.
68. Bird, S.; Loper, E.; Klein, E. *Natural Language ToolKit (NLTK) Book*; 2009;
69. Denny, M.J.; Spirling, A. Text Preprocessing for Unsupervised Learning: Why It Matters, When It Misleads, and What to Do about It. *Political Analysis* **2018**, doi:10.1017/pan.2017.44.

70. Rehurek, R.; Sojka, P. Gensim--Python Framework for Vector Space Modelling. *NLP Centre, Faculty of Informatics, Masaryk University, Brno, Czech Republic* **2011**, *3*.
71. Denny, M.J.; Spirling, A. Text Preprocessing For Unsupervised Learning: Why It Matters, When It Misleads, And What To Do About It. *Political Analysis* **2018**, *26*, 168–189, doi:10.1017/PAN.2017.44.
72. Syed, S.; Spruit, M. Full-Text or Abstract? Examining Topic Coherence Scores Using Latent Dirichlet Allocation. In Proceedings of the Proceedings - 2017 International Conference on Data Science and Advanced Analytics, DSAA 2017; 2017.
73. Debortoli, S.; Müller, O.; Junglas, I.; vom Brocke, J. Text Mining for Information Systems Researchers: An Annotated Topic Modeling Tutorial. *Communications of the Association for Information Systems* **2016**, doi:10.17705/1cais.03907.
74. Röder, M.; Both, A.; Hinneburg, A. Exploring the Space of Topic Coherence Measures. In Proceedings of the WSDM 2015 - Proceedings of the 8th ACM International Conference on Web Search and Data Mining; 2015.
75. Roberts, M.E.; Stewart, B.M.; Tingley, D. Navigating the Local Modes of Big Data: The Case of Topic Models. In *Computational Social Science: Discovery and Prediction*; 2016 ISBN 9781316257340.
76. Chang, J.; Boyd-Graber, J.; Gerrish, S.; Wang, C.; Blei, D.M. Reading Tea Leaves: How Humans Interpret Topic Models. In Proceedings of the Advances in Neural Information Processing Systems 22 - Proceedings of the 2009 Conference; 2009.
77. Supahar Applying Content Validity Ratios (CVR) to the Quantitative Content Validity of Physics Learning Achievement Tests. In Proceedings of the Proceedings of the 1st International Conference on Research, Implementation, and Education of Mathematics and Science; FMIPA UNY: Yogyakarta, May 2015.
78. Keane, T. Leading with Technology: 21st Century Skills = 3Rs + 4Cs. *Australian Educational Leader* **2012**, *34*.
79. OECD Programme for International Student Assessment (PISA) Results from PISA 2018. *Oecd* **2019**.
80. Pelegrino, J. Teaching, Learning and Assessing 21st Century Skills. In; 2017.
81. Pellegrino, J.W.; Hilton, M.L. *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*; 2013;
82. Suyanto, S. The Implementation of the Scientific Approach through 5ms of the Revised Curriculum 2013 in Indonesia. *Cakrawala Pendidikan* **2018**, *37*.
83. Efron, B.; Stein, C. The Jackknife Estimate of Variance. *The Annals of Statistics* **2007**, *9*, doi:10.1214/aos/1176345462.
84. Houston, S. Lessons of COVID-19: Virtual Conferences. *Journal of Experimental Medicine* **2020**, *217*, doi:10.1084/JEM.20201467.
85. Hardiono, H.; Umar, M.A.; Hidyantari, E. Zonation System Policy Implementation in the Admission of New Students in the City of Surabaya, East Java, Indonesia. *The International Journal of Business & Management* **2020**, *8*, doi:10.24940/theijbm/2020/v8/i12/bm2012-003.
86. Center of Curriculum and Instruction; Council of Educational Standard Curriculum and Assessment *Academic Manuscript: Principles of Developing Differentiated Instruction for Flexible Curriculum as Independent Learner Manifestation*; Purba, M., Saad, M.Y., Falah, M., Eds.; Ministry of Education Culture Research and Technology, 2021;