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The Most-cited Educational Research Publications on Differentiated Instruction: A Bibliometric Analysis

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Abstract: The amount of empirical research conducted in the area of differentiated instruction (DI) is overwhelming, necessitating this bibliometric analysis in order to produce an overview of literature on the topic. The objective of this study is to identify the characteristics of the most-cited educational research published on the topic of DI using science mapping and multi-dimensional bibliometric analysis methods. To answer the research questions which were related to: i) publication, ii) authorship, iii) authors' keywords, and iv) journals, a total of 100 articles published between 1990 and 2018, generated from SCOPUS, were analysed. The results showed that the most-cited articles and the number of publications were highest between 1995 and 2011. With a total of 545 citations "A Time for Telling", published in the Journal of Cognition and Instruction (1998), was the most cited. The most significant keywords were: a) differentiated instruction, b) differentiation, c) curriculum, d) mathematics, and e) reading. The analysis showed that there were 283 authors who contributed to the 100 articles, and amongst them Carol McDonald Connor was the greatest contributor. It was also revealed that the great majority of the most-cited publications were from Q1-ranked journals. These findings inform scholarly efforts adopted in developing a diverse knowledge base in the field. The findings are important to scholars as they provide an overview of the progress of research on the topic of DI.

Keywords: *Bibliometrics, citation analysis, differentiated instruction.*

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Introduction

Differentiated instruction (DI) is a teaching approach based on the premise that instructional approaches should vary and be adapted in order to take account of individual, unique and diverse students in classrooms (Muthomi & Mbugua, 2014). As an educational approach, DI acknowledges a wide range of students' readiness levels, interests, and learning modes through the means of proactive, flexible, varied, knowledge-centered, and learner-centered strategies (Tomlinson et al., 2003). Hence, owing to its practicality and importance, the approach is recognized as a theory of action which is supported by both researchers and practitioners (Abbati, 2012). In this paper, DI is defined as an instructional approach which teachers proactively adopt to cater for and hopefully meet the diverse needs of students.

Literature is full of reports presenting empirical evidence on various aspects related to DI. A profusion of studies, articles, and books appears on DI in all academic databases. Relating to the topic, some of these studies investigated the effectiveness of DI (e.g. Reis, Mccoach, Little, Muller & Kaniskan, 2011; Ruys, Defruyt, Rots, & Aelterman, 2013; Seiler, 2014; Tomlinson et al., 2003; Tulbure, 2011), while others explored teachers' beliefs, perceptions, and attitudes (e.g. Nedellec, 2015; Reilly & Migyanka, 2016; Robinson, Maldonado, & Whaley, 2014; Wan, 2015). Many of the studies have examined teachers' knowledge (e.g. Stollman, Meirink, Westenberg, & Driel, 2019; Taylor, 2016; Wu & Chang, 2015;Younis, 2013), as well as their challenges (e.g. Merawi, 2018; Nedellec, 2015; Robinson et al., 2014; Wan, 2016) relating to, or stemming from, DI. Likewise, with regard to implementation of the strategies, several research initiatives were carried out on areas pertaining to: a) the overall implementation of DI (e.g. Melesse, 2015; Siam & Al-Natour, 2016), b) factors that influence implementation (e.g. Brevik, Gunnulfsen, & Renzulli, 2018; Suprayogi et al., 2017), and c) various differentiation strategies teachers use in the implementation (e.g. Etienne, 2011; Pentimonti et al., 2017).

The above list of publications indicates the fact that there is an abundance of studies on DI which makes it difficult for researchers to produce an overview of the topic. The multitude of research papers spreading over numerous different

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journals makes it hard to identify which of those publications are the most influential in the field. However, advanced bibliometric mapping and clustering techniques make it possible to visualise and structure complex research literature. Through a bibliometric analysis, scholars can identify and classify research hotspots, and explore the updated insights in a particular field, such as DI (Gondivkar et al., 2018).

Despite the profusion of the available literature on DI, to the best of our knowledge, no bibliometric studies on the topic have been reported to date. Visualized representations of bibliometric maps and clustering techniques that enable an overview of the various aspects of DI appear, so far, to have been neglected in the existing literature. There has not been a single bibliometric study of the top-cited papers in the field showing how characteristics of the publications changed over time. Hence, owing to all the above reasons, a new citation analysis on this topic is justified. Therefore, the current study has been carried out to: a) assess the volume of scientific publications related to DI in general, as well as b) perform a bibliometric analysis to describe the characteristics of the most-cited studies in the field.

Bibliometrics is one of the quantitative techniques used to identify the pattern of publication authorship and citation used within a research area over a period of time, thereby offering insight into the dynamics of the area (Mathankar, 2018). Bibliographic review studies are important, as the concept "bibliography" is prevalent and thus given importance in research field (Batanero, Rueda, Fernandez-Cerero, & Martinez, 2019). Such review papers help to obtain information through analysis of top-cited papers and their citation rates in a research field (Fardi et al., 2011). More and more of the research community, publishers, and policy makers realize the importance of the evaluation processes, and particularly the use of bibliometric indicators based on author publication practices and upon journal editorial practices (Moed, 2005). Therefore, given the importance of such a scientific and fundamental analysis regarding publications of interest, the purpose of this study was to perform a bibliometric analysis of the 100 most-cited papers in the field of DI, as well as to report their overall topographies. The reason for targeting the 100 most-cited articles is because these articles are deemed to be the most well-known and most prominent publications demonstrating up-to-date academic information, progress, and tendencies in the field. Hence, this paper engaged science mapping to elicit essential bibliometric details of the said articles by addressing the following six research questions:

1. What is the pattern of publication and the areas covered in the 100 most-cited educational research publications on differentiated instruction?
2. What is the pattern of citation of the 100 most-cited educational research publications on differentiated instruction?
3. What are the most frequently used authors' keywords among the 100 most-cited educational research publications relating to differentiated instruction?
4. What is the pattern of collaboration and contribution of distinctive authors and institutions towards the publication of the 100 most-cited educational research publications on differentiated instruction?
5. Which countries contributed most to the publication of the 100 most-cited educational research publications on differentiated instruction?
6. What are the publication characteristics of the journals in which the 100 most-cited educational research publications on differentiated instruction were published?

It is arguable that investigating the most productive and influential researchers, journals, and universities leading the development in the field is a necessary and helpful activity. The sketch of the scientific structures used in this bibliometric analysis provides new insight into the breadth and depth of the relevant publications in the existing literature. It is believed the results of this study will provide scientific researchers with crucial knowledge about: i) DI's research status and frontier trends, ii) the current research interests, and iii) other important information that would lead to further investigation of this topic.

Method

Search strategy

In this study the Elsevier SCOPUS database was selected as the source for searching publications related to the topic of the study. There are other significant bibliographic databases, such as ISI Web of Science (WoS) and Google Scholar, which are widely used for research evaluations (Martín-Martín, Orduna-Malea, Thelwall, & Delgado Lopez-Cozar, 2018). However, for this study only the SCOPUS database was used as it covers a much wider range of materials compared to other databases (Salisbury, 2009). SCOPUS covers about 70% more sources compared to the WoS (Lopez-illescas, Moya-anegon, & Moed, 2008). Google Scholar was not used because it cannot produce consistent search results, and the indexing procedures are not as rigorous as SCOPUS and ISI (WoS).

An electronic search of the SCOPUS database was performed on August 17, 2019 using the term "differentiated instruction". The keyword search was restricted to the presence of the searched term in the articles' titles, abstracts,

and keywords. The initial search yielded a total of 1,101 documents, after which the search was refined by restricting it to the following inclusion and exclusion criteria as set out below

Inclusion and exclusion criteria

The inclusion criteria were: i) papers in the field of social science, ii) journal articles written in the English language, and iii) articles published between the years 1990 to 2018. The duration was selected owing to the boost in publication due to the evolution of e-journals. The extension of the internet and the possibility of timely mass distributions increased since the year 1990 (Keefer, 2001). Articles that did not fit into the above three inclusion criteria were excluded.

Data extraction and cleaning

Based on the above parameters, the advance search resulted in the identification of 427 documents. Once these 427 documents were identified a data cleaning process was carried out, checking incomplete or wrongly entered entries. Two specific steps were adopted in this process: i) verifying the entries of the fields (columns) in order to ensure any important data is not missed, and ii) cross-checking the data in the columns to confirm whether data content of the fields are aligned with the field title. When any wrong or missing entries were identified, they were deleted accordingly.

Once the final data set was confirmed, the list was sorted, based on the citation count, from highest to lowest. Afterwards, the 100 most-cited articles were selected and the bibliometric data of the selected articles were downloaded. The list was downloaded with: a) author(s), b) author(s) ID, c) title, d) year, e) sources (journal title), f) volume, g) issue, h) times cited, i) link, j) abstract, k) author keywords, and l) publisher information for further analysis in this study. A flow chart of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) declaration figure showing the flow of the search is presented in Figure 1.

Bibliometric analysis

The bibliometric analysis components included in the present study are: i) the number of citations, ii) authors, iii) journals, iv) countries, v) institutions, vi) year of publication, and vii) author keywords of the 100 papers selected for this bibliometric analysis. Following is an explanation of the measures and procedures adopted when analyzing and presenting the data from these variables.

First, for brevity and ease of presentation, when calculating the distribution of citations, the number of years was divided into equal groups of 4-year intervals. The four-year interval was chosen for the practical reason that the total duration of 28 years (from 1990 to 2018) can be evenly divided into seven categories respectively. The same procedure was applied to analyze the average citation per paper.

With regard to the keywords, only authors' keywords were considered for the analysis. The total number of keywords of the 100 articles is 186. A threshold of 2 was applied during the analysis of these keywords. Visualization of the frequency of the keywords, together with their link strengths, is presented in the results. As seen from the presentation, the bubble size refers to the total number of times the keyword is repeated in the articles, while line thickness and color refer to link strength and clustering, respectively.

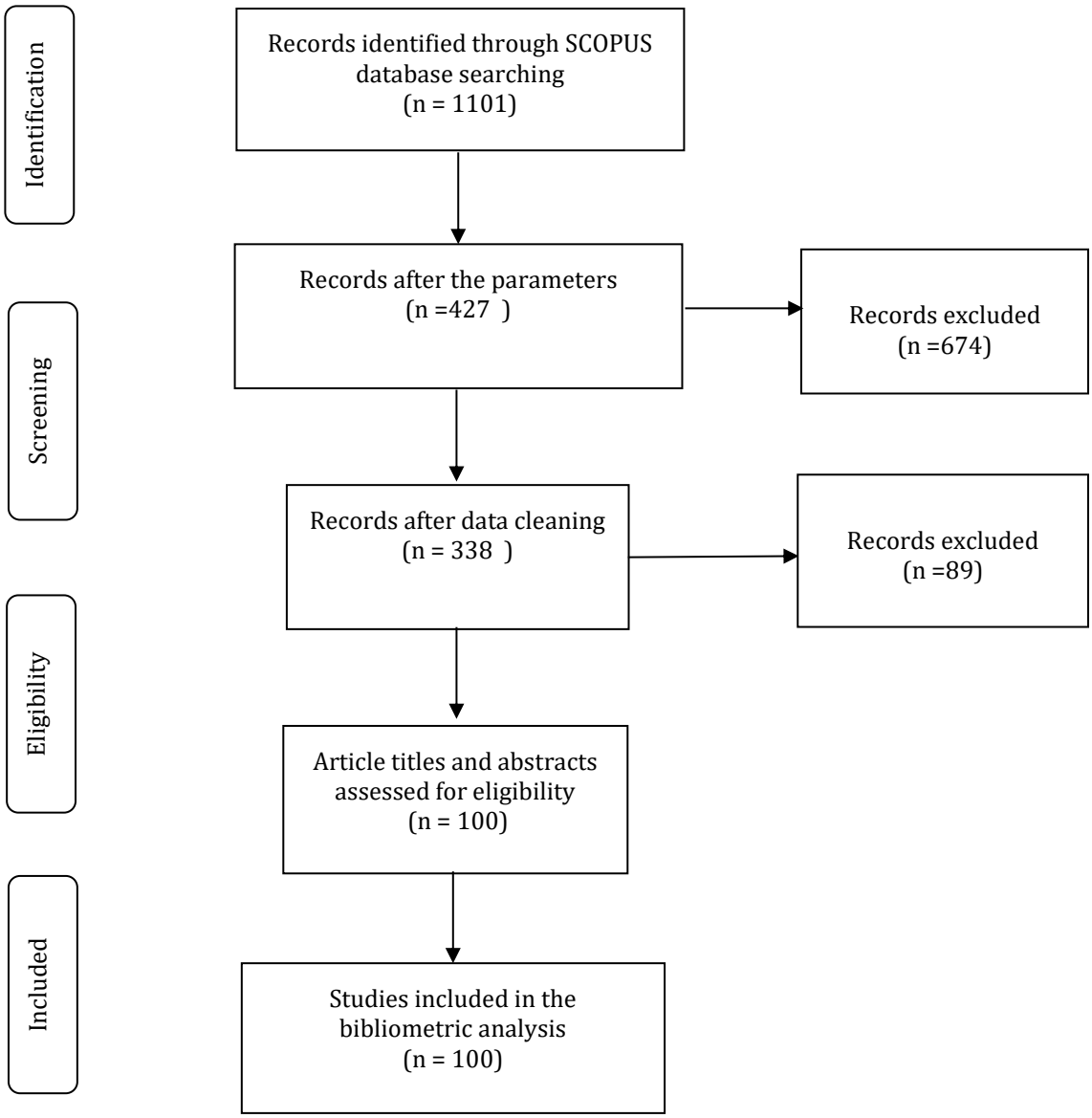

Figure 1. PRISMA flow diagram showing the flow of the search in the identification and screening of sources for the bibliometric analysis of DI research (DI: Differentiated Instruction; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

The authorship analysis includes the collaboration of distinctive authors and details about their individual publications. During the analysis, authors without a link were excluded as one of our aims was to discover the existing collaboration between these authors. Excluding such cases would not have an adverse effect on the results as those authors had just one publication indicating only a small contribution.

In conducting the analysis of the affiliated institutions, faculties/institutes/centers within a university were treated as independent entities. However, when such details were not available, the university (as a whole) was considered as one entity. Moreover, a thesaurus file was used to replace names that are the same but stated differently in the extracted data.

With regard to the affiliated countries, the country of publication is where the authors' institutions are located. There were 43 countries from which the selected 100 articles originated; amongst these only 11 countries indicated collaborative attributes with other countries, and they were taken for the analysis.

The last component of the analysis relates to the journals in which the selected articles were published. For brevity, during the analysis, only the journals which published at least three articles were included. The journals are ranked according to the number of publications followed by their total citations.

Results and Discussion

This section presents the results of the analyses that were carried out, as outlined above. The results are presented in the order of the research questions. Presentation of the analyses includes graphs, tables, and visualization of bibliometric networks. A discussion about each analysis is provided along with the respective results.

What is the pattern of publication and the areas covered in the 100 most-cited educational research publications on differentiated instruction?

Trend in publications: Figure 2 shows the total number of papers published between 1990 and 2018. As seen from Figure 2, the number of publications on the topic was roughly the same until 2006, with some fluctuations over the years from 1990. The number of publications during these years varied between 3 and 8. However, from 2007 onwards there is a boost in publications with an overall constant rise until 2017 when it reached the number 46, the highest over the period. This indicates the increased interest of researchers, as well as publishers, in the topic of DI.

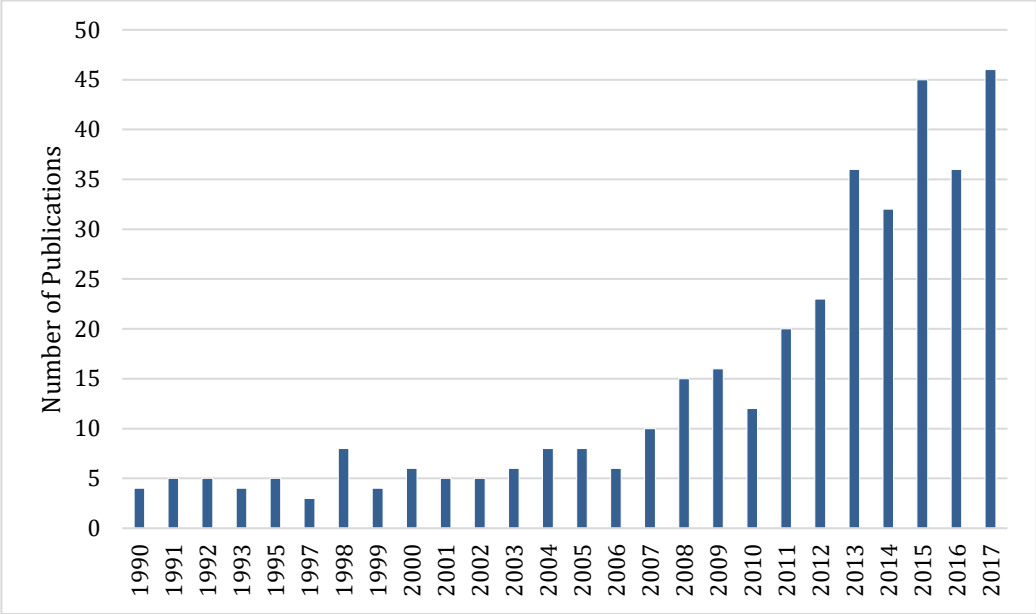

Figure 2. Number of publication by year (1999-2018)

Areas covered: Table 1 summarizes the distribution of DI related topics covered in the 100 most-cited articles. The table also has the articles' corresponding reference numbers as given in Appendix A. Content analysis of the selected articles' titles and abstracts revealed that there was a total of 20 distinctive areas in which the studies were conducted. Amongst these areas, the highest number of papers addressed the various instructional strategies teachers use in teaching and learning (*n*=25). The second highest number of papers combined DI with students' literacy development (*n*=18). Some of these 18 papers tried to assess students' language ability, word recognition or vocabulary acquisition, while others attempted to evaluate language ability through the use of resource rooms. Research on students' reading ability and/or language development is important as those two issues have become a major concern for all educational stakeholders due to their impact, either positive or negative, on both an individual's academic life and on his/her social life (Akyol & Boyaci-Altinay, 2019; Osei, Liang, Natalia, & Stephen, 2016). Hence, as revealed from the analysis, the importance on language development for knowledge acquisition is reflected in the selected studies.

Table 1. Sub-areas Studied in the 100 Most-cited Papers and their Total Number of Articles

No	Area of Research	No. of Articles (References)
1	Assessing the Effect of DI in general	7 11 12 14 17 31 79 82 98
2	Between Countries	2 16 64
3	Implementation of DI	10 94 12 14 21 60 73 80 81 92
4	Institutional (School-based) Variables	7 13 43 50 57 62 86 91
5	Instructional Strategies	25 2 10 12 14 20 21 22 24 25 27 34 39 41 45 48 51 58 61 67 68 70 79 92 95 98
6	Learning Disabilities	3 58 65 87
7	Learning Styles and Preferences	2 40 52
8	Literacy Development	18 6 14 17 19 31 34 48 49 53 58 61 69 71 77 79 87 91 92
9	Mathematics	5 45 52 58 64 73
10	Parent Involvement	2 35 97
11	Professional Expertise	3 28 32 50
12	Review of Literature on DI	2 7 15
13	School-based DI	2 46 47
14	Science	5 81 82 93 98 100
15	Student Development and Well-being	5 8 9 17 26 44
16	Students' Understanding and Conceptualization	6 5 26 45 56 66 98
17	Teacher Traits and Qualities	5 3 13 16 20 43
18	Teachers' Perceptions	2 86 94
19	Teachers' Knowledge	2 50 100
20	Use of ICT	4 2 7 33 96

Note: Some of these studies covered more than one topic and were classified depending on the aim of the study and the main outcomes.

Amongst the 100 articles, studies that explicitly explored teachers' knowledge base as well as their perceptions and attitudes about DI were few (n=2), compared to the wide range of investigations into other areas. However, studies that were aimed at investigating the impact of DI on different curricular subjects (e.g. science, mathematics and language) were found to be voluminous. Much of this research compared students' academic improvement in relation to teachers' use of DI strategies. In these studies, researchers analyzed the importance of altering instructions for students' understanding and conceptualization of curricular content. Additionally, several researchers were interested in identifying the level of teachers' implementation of DI in their teaching and learning activities. Thus, the results showed that researchers have explored a wide range of areas in the field of DI.

What is the pattern of citation of the 100 most-cited educational research publications on differentiated instruction?

The citation analysis is looked at from three different perspectives: i) total citation, ii) average citation by year, and iii) normalized citation.

Analysis by year: Figure 3 shows the total number of citations and number of citations per paper for articles published between 1990 and 2018. The distribution of the number of citations is presented based on a 4-year span. As seen from the graph (Figure 3), the total of the citations dramatically increased from 139 in 1994 -1997 to 1011 in 1998-2001. However, there was a significant decline in the years 2002 to 2005. Subsequently, the citations regained momentum from 2006 to 2013, reaching a peak between 2006 and 2009. During the last phase, once again the citation numbers decreased as this duration has the shortest period of time to increase the citation count.

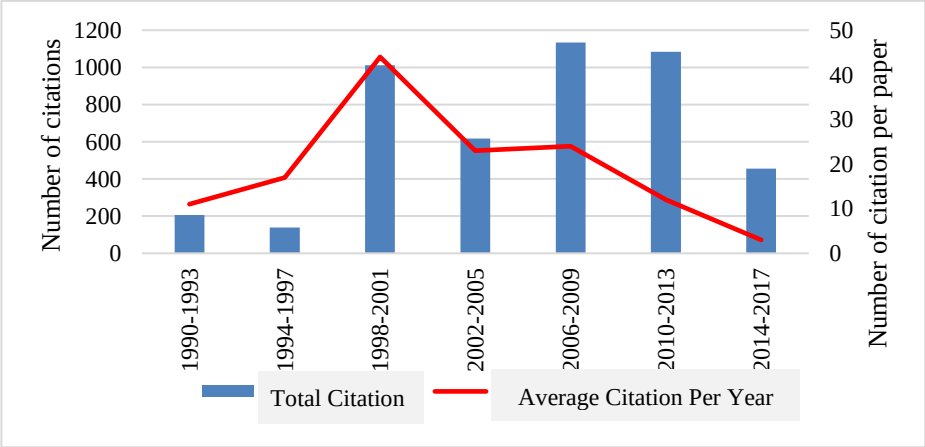

Figure 3. Citation by year (1990-2018)

In 1998-2001 the citation average attains its peak with 44 citations per paper. Although the highest total number of citations is achieved in 2006-2009, the average citation per paper during this period, at 24 citations per paper, is lower than that of 1998-2001. The average citation per paper is falling from 2006-2009 onwards. Similar to the case of total citations, this trend may look different after several years, as the number of citation will continue to increase with time, while the publication in those years will remain unchanged.

Number of citations and normalized citation: Table 2 shows publication details including: a) the author, b) journal name, c) journal citations core, d) number of citations, and e) normalized citation of the selected articles. The normalized citation indicator offers an expression of the average number of citations of the publications, normalized for field, publication year, and document type (Aksnes, Langfeldt, & Wouters, 2019; Mingers & Kaymaz, 2019; Zitt, Ramanana-Rahary, & Bassecoulard, 2005).

As seen in the table in Appendix A, the year of publication of the selected articles extends to a total of 27 years; from 1990 to 2017. It is likely that the publications of 20 years ago would gain more citations than articles published more recently. Therefore, it is unfair to compare articles with varying publication years, simply based on a citation count. The results would be misleading if citations were not normalized for the number of years after publication; hence, in this article, the citations were normalized based on the year of publication.

Table 2 presents the citation details of the selected articles. For brevity, out of the selected 100 articles, only 10 are included in Table 2. The full list is given in Appendix A.

Table 2. Number of Citations and Normalized Citation

No.	Authors	Title of the Article	Year	CC	NC	Journal Name	JCS
1	Schwartz D.L.	A time for telling	1998	545	26	Cognition and Instruction	3.7
2	Davies R.S.	Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course	2013	277	46	Educational Technology Research and Development	3.29
3	Valli L.	The changing roles of teachers in an era of high-stakes accountability	2007	272	23	American Educational Research Journal	4.14
4	Kunter M.	Who is the expert? Construct and criteria validity of student and teacher ratings of instruction	2006	136	10	Learning Environments Research	2.11
5	Harrison A.G.	Investigating a Grade 11 student's evolving conceptions of heat and temperature	1999	113	6	Journal of Research in Science Teaching	4.31
6	Vaughn S.	Broken promises: Reading instruction in the resource room	1998	91	4	Exceptional Children	3.37
7	Zydney J.M.	Mobile apps for science learning: Review of research	2016	86	29	Computers and Education	7.72
8	Laukenmann	An investigation of the influence of emotional factors on learning in physics instruction	2003	82	5	International Journal of Science Education	1.89
9	Shaw S.R.	Hospital-to-school transition for children with chronic illness: Meeting the new challenges of an evolving health care system	2008	78	7	Psychology in the Schools	1.54
10	Hooper S.	Cooperative learning and computer-based instruction	1992	71	3	Educational Technology Research and Development	3.29

Notes:- CC: Citation count is the total number of times the article has been cited; NC: Normalized citation is the average number of times an article is cited per year since its publication. It is calculated by dividing the CC by the number of years after publication of the article; JCS: Journal cite score is a journal ranking score provided by SCOPUS which is based on the citation impact of the journal.

As shown in Table 2, publication 1 (Title: *A time for telling*) is the highest cited (545 citations) among the 100 most-cited articles. The article was published in the journal *Cognition and Instruction* (1998). When the citation is normalized for the number of years after publication (normalized citation), this publication would be dropped to third place with an average of 26 citations per year.

With regard to the second highest cited publication (Title: *Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course*) with 277 citations, the article would be ranked first based on the average citation per year (46 citations). When the third highest (272 citations) cited article (Title: *The changing roles of teachers in an era of high-stakes accountability*) is analyzed, the findings reveal that it would reach the 4th place with an average of 23 citations per paper.

The above results suggest that the total number of citations could be misleading when analyzing the citation metric; hence, it is more meaningful to consider the average citations per paper and normalized citations per year. Normalization of citations, by taking into account the time of publication, is necessary since use of raw citation counts fluctuate in time (Purkayastha, Palmaro, Falk-krzesinski, & Baas, 2019).

What are the most frequently used authors' keywords among the 100 most-cited educational research publications relating to differentiated instruction?

According to Zhang et al. (2019), the top authors' keywords can denote indications of the research priorities and interests of scientists and researchers in the field. Therefore, it was felt important to examine the list of keywords authors used in the selected publications included in this bibliometric study. Accordingly, the analysis of the 100 most-cited articles on differentiated instruction conducted using VOSviewer yielded a total of 186 authors' keywords. When a threshold of 2 was applied to these keywords, the results showed 20 specific keywords which were used on more than 2 occasions. The co-occurrence network of these most frequently used keywords is shown in Figure 4. As seen from Figure 4, the important concepts embedded in the selected publications can be mapped into four major clusters.

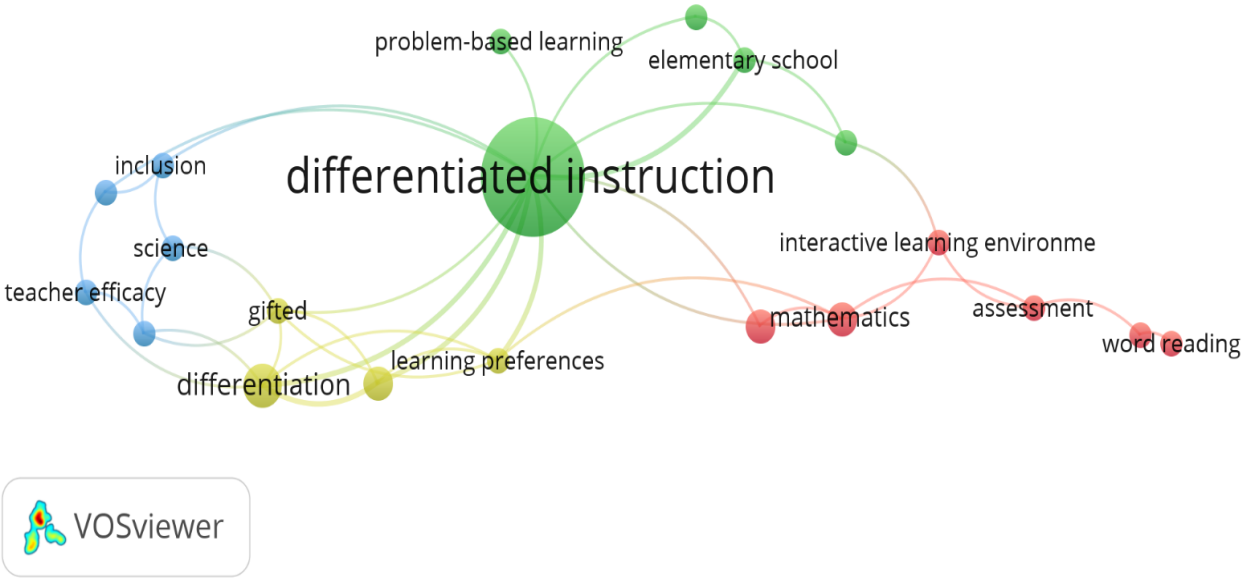

Figure 4. Co-occurrence network of the most frequently used author keywords.

According to the clusters, the most significant keywords were: i) *differentiated instruction*, ii) *differentiation*, iii) *curriculum*, iv) *mathematics*, and v) *reading*. Other than the topic 'differentiated instruction' the term 'differentiation' had the highest link strength among all the authors' keywords. The keyword 'differentiation' had the highest link strength as it might be used as a substitute for the topic of differentiated instruction in the selected studies. The analysis reveals that the term 'differentiated instruction' was highly associated with the issues of: a) curriculum, b) gifted, and c) learning preferences. Literature has several instances where researchers showed interest in studying the link between these highly associated terms together with differentiated instruction (see Gettinger & Stoiber, 2012; Hertberg-Davis, 2009; Joseph et al., 2013; Othman et al., 2016; Ysseldyke et al., 2004).

The keyword with the second highest link (with a frequency of 3) was the term '*mathematics*' which received a link strength of 5. The concepts related to mathematics included *assessment, interactive learning, environments, reading, vocabulary*, and *word reading* which all belong to the same cluster. Although the terms *reading, vocabulary*, and *word reading* showed link to the term 'mathematics', those terminologies are major components of language learning and language acquisition (Laufer, 2003; Nagy & Townsend, 2012). A major reason for researchers to combine the concepts of these two disciplines would be their individual interest in studying students' literacy and numeracy levels in association with differentiated instruction.

As indicated from the analysis, the keywords: *elementary school, mobile learning, teaching methods,* and *problem-based learning* formed cluster 3 with an equal occurrence of 2 for each term. Amongst these keywords, 'elementary school' registered the highest link strength (4) while the rest of the keywords all had weaker links. Since most of these

terminologies were related to instructional strategies (*mobile learning, teaching methods, problem-based learning*), it is believed that researchers were interested in understanding these instructional concepts when they are applied with differentiated instruction in their respective studies.

The final cluster had 5 authors' keywords with more or less equal link strengths: *professional development* (link strength = 4), *inclusion* (link strength = 3), *science* (link strength = 3), *self-efficacy* (link strength = 3), and *teacher efficacy* (link strength = 3). In comparison with keywords from the rest of the clusters, it is evident that most of these terms are focused on teachers rather than students (*professional development, self-efficacy, and teacher efficacy*). Therefore, it can be understood why this set of words stayed furthest from the cluster which had more student related concepts such as: i) interactive learning, ii) environments, iii) reading, iv) vocabulary, and v) word reading. Hence, in the 100 selected studies researchers have explored not only the effect of differentiated instruction on student achievements, but also the impact of professional development and teachers' efficacy in association with teachers' practice of differentiated instruction.

What is the pattern of collaboration and contribution of distinctive authors and institutions towards the publication of the 100 most-cited educational research publications on differentiated instruction?

Authorship analysis: The analysis of authorship shows that there were a total of 283 authors who contributed to the 100 most-cited articles. Amongst these 283 authors, 20 authors had links of collaboration. Figure 5 represents the co-occurrence network of the collaboration of these distinctive authors. It can be seen that there are three distinct clusters of co-authorship groupings.

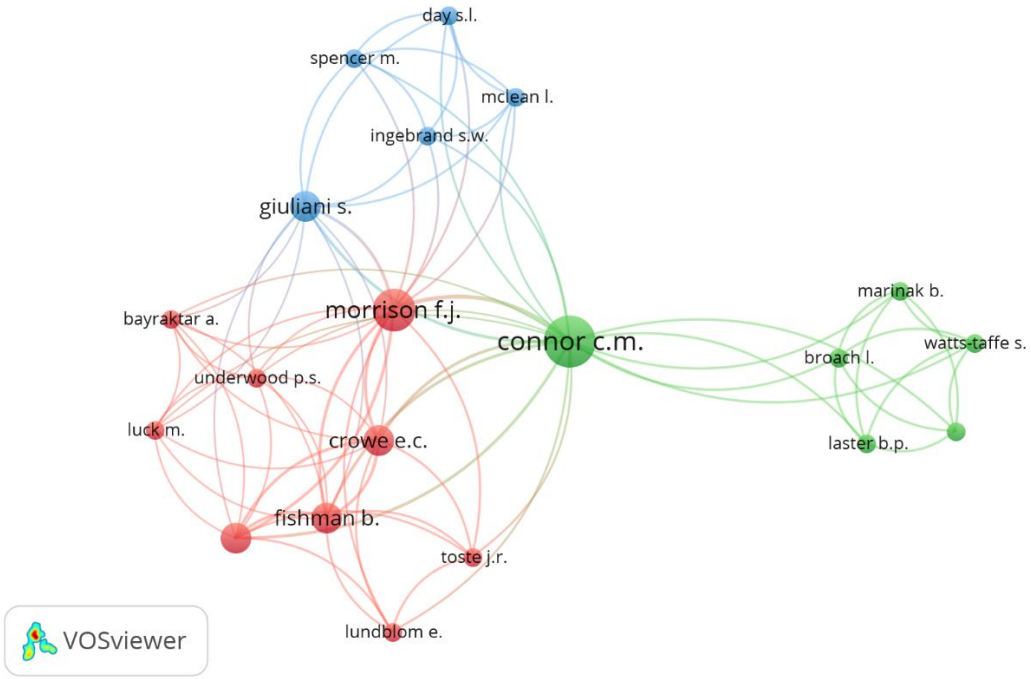

Figure 5. Co-occurrence network of the collaboration of distinctive authors

The most significant fact observed from the analysis is that in terms of the number of the most-cited articles, Carol McDonald Connor has contributed to the highest number of publications (4 articles) with a total link strength of 25 overall. The author has contributed almost equally to the three clusters while also being identified as the leading author in cluster 2. It was discovered that Carol McDonald Connor published those articles in collaboration with a set of co-authors, and she was the first author of three out of four identified articles. These four articles focused on language and literacy skills together with whole-class, small-group, or independent student instruction; all topics that were aligned to students' needs. The studies revealed the positive effects of the individualized student instruction intervention. Hence, it is worthy to note that Carol McDonald Connor was one of the most prolific authors of the publications involved in this study; particularly in the way she presented tailored instruction as a key to improve language and literacy skills.

The second most prominent author identified from the analysis is Frederick J. Morrison who contributed to three of the selected articles with a total link strength of 20 in overall. The author's research focused on the nature and sources of literacy acquisition in children during the transition to school. With a psychology background and interest in cognitive development in school-age children, the author has published a large body of original papers in numerous reviewed journals since 1970. The analysis also revealed that after Carol McDonald Connor, Frederick J. Morrison has obtained the second highest citation for his three publications which are included amongst the 100 most-cited articles. Hence, these authors were the most active to be identified in this study.

In addition to the above, the four authors: i) Crowe E.C., ii) Fishman B., iii) Schatschneider C., and iv) Giuliani S. each had two publications, which were included in the selected 100 articles. Each of the remaining authors has just one publication. Additionally, it was identified that Crowe E.C., Fishman B., and Schatschneider C. had citation counts of 106 each, while for Giuliani S. the citation total was 85.

Hence, amongst the 283 authors who contributed to the top 100 articles, it was discovered that scholarly work of the above authors made the highest contributions in terms of the number of publications, citation count, and collaboration. The rest of the authors made comparatively less contributions as their number of publications and citations were less.

Institution analysis: The analysis related to the authors' institutions discovered that many of the institutions did not engage in collaborative publications regarding the topic of differentiated instruction. It was found that only 24 out of the 186 institutions had some connections with other institutions. According to the analysis, Florida Center for Reading, University of Connecticut, and the College of William and Mary were the top three collaborators; their collaborations numbering 17, 12 and 7 respectively. It was also observed that these three institutions were ranked in the same order when sorted according to the number of publications; they contributed to the publication of 5, 4 and 3 documents respectively.

Figure 6 shows the network view of the above-mentioned three institutions where: A = Florida Center for Reading; B = the University of Connecticut; and C = the College of William and Mary.

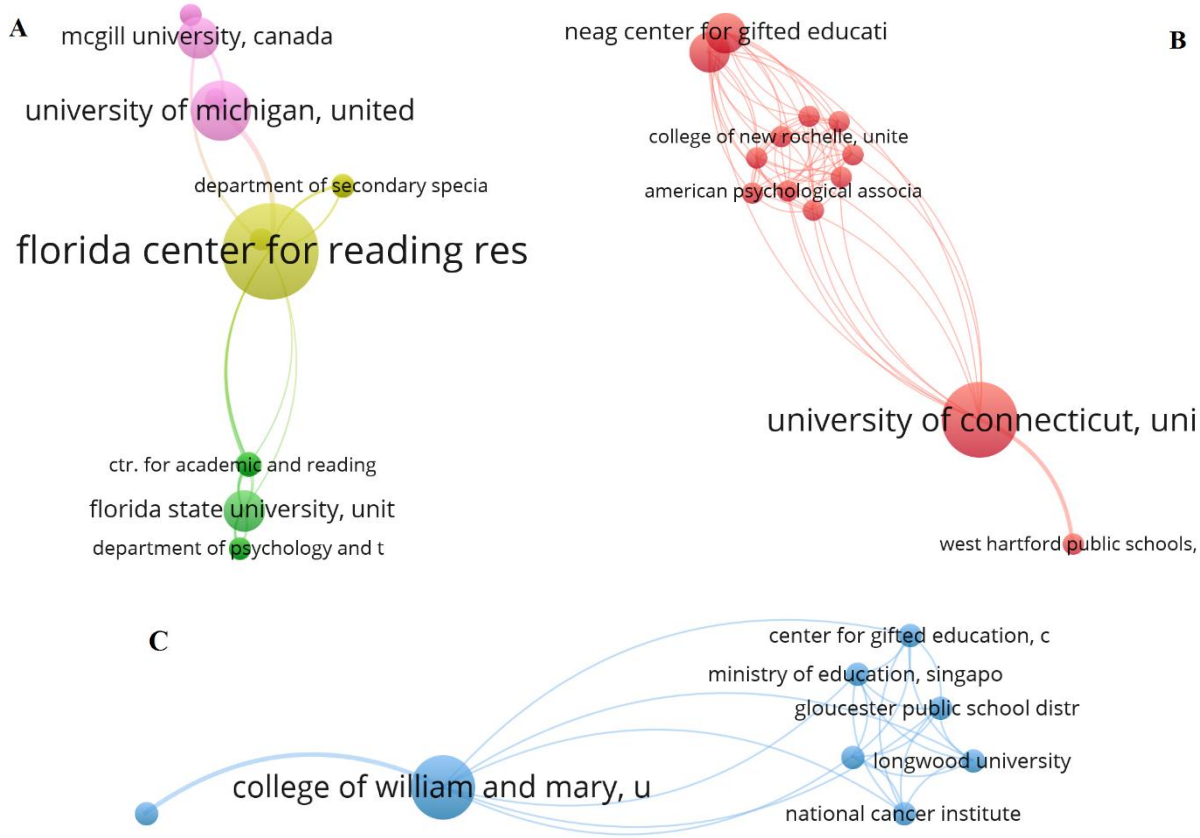

Figure 6. Network view of the three most active collaborators (institutions)

With regard to Figure 6(A), the results show evidence of collaboration among various institutions within the university (Florida State University) as well as outside the university. In this regard, collaborative work was done with many institutions out the university including, among others, University of Michigan and Arizona State University (USA), McGill University (Canada), and Konyang University (South Korea). Similar findings were observed from Figure 6(B) and 6(C); that collaboration occurred within and outside the universities (the University of Connecticut and the College of William and Mary). However, the total number of collaborative links to outside institutions is less in Figure 6(B) and 6(C) as compared to Figure 6(A). In sum, these results indicate that better collaboration, both within and among universities, has resulted in more scholarly output in terms of publications.

Which countries contributed most to the publication of the 100 most-cited educational research papers on differentiated instruction?

Figure 7 shows the contributions from various countries to the production of the 100 most-cited articles. Only those countries which showed any collaboration with other countries in the publication of the selected articles are included in the figure as these countries also happened to be the top contributors.

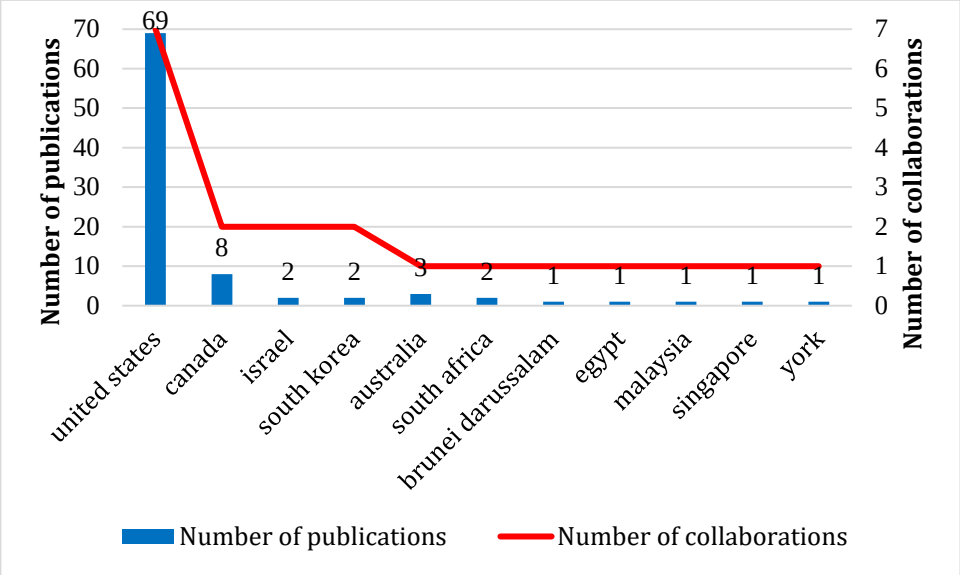

Figure 7. The contribution of various countries

As indicated in Figure 7, with 69 publications the USA was behind the greatest contribution to the most-cited scholarly work on differentiated instruction. This total is followed by Canada with 8 publications. Although few in number of publications, the graph revealed contribution from a range of locations including Asia, Africa, Middle East, Australia, and America. Surprisingly, none of these publications came from a European country.

With regard to collaboration among countries, results in Figure 7 indicate that the USA has collaborated with 7 countries representing the maximum collaboration among all. Moreover, as seen from the results, the graph of the number of collaborations falls rapidly; corresponding to the fall in the number of the most-cited publications. For instance, Canada, which has the second highest number of publications, also has the second highest number of collaborations (with 2 countries). These results suggest that there is a positive association between the number of most-cited publications and international collaboration involved in those publications.

What are the publication characteristics of the journals in which the 100 most-cited educational research papers on differentiated instruction were published?

Table 3 shows the journals which published the greatest number of the most-cited articles. For brevity, only the journals which published at least three articles are included in the table. These journals are ranked according to the number of publications followed by total citations. As seen from the results, the majority of the most-cited publications on differentiated instruction appeared in Q1-ranked journals. However, there are some publications in Q2 and Q3-ranked journals as well.

Table 3. Top journals which published the majority of the 100 most-cited articles.

No	Journal Name	TP	TC	CPP	CiteScore[1]	SJR[2]
1	Gifted Child Quarterly	5	170	34.00	1.57	Q2
2	Exceptional Children	4	199	49.75	3.34	Q1
3	Educational Leadership	3	370	123.33	3.29	Q1
4	Educational Technology Research and Development	3	179	59.67	1.89	Q1
5	Elementary School Journal	3	135	45.00	1.34	Q1
6	International Journal of Science Education	3	133	44.33	3.45	Q1
7	Learning Disability Quarterly	3	90	30.00	0.20	Q3
8	Teachers College Record	3	71	23.67	3.45	Q1
9	Teaching and Teacher Education	3	64	21.33	1.52	Q1

TP = total publication; TC = Total citations; CPP = citation per publication
[1]Figures for 2018 provided by SCOPUS
[2]Figures for 2018 provided by Scimagojr

As indicative from the above table, the journal '*Gifted Child Quarterly*' which has the most number of publications (5) is ranked Q2. Similarly, '*Learning Disability Quarterly*', which is a Q3-ranked journal, secured the 3rd position based on the number of publications. It is also observed that all the above top journals are somehow related to certain categories such as: a) inclusive education (*Gifted Child Quarterly, Exceptional Children,* and *Learning Disability Quarterly*), b) teaching and teacher training (*International Journal of Science Education, Teachers College Record,* and *Teaching and Teacher Education*), c) school leadership (*Educational Leadership*), as well as d) technology and research in teaching (*Educational Technology Research and Development*). The wide scope of these journals indicates the significance of differentiated instruction to the overall improvement of teaching and learning processes in general. Similarly, the two journals *Gifted Child Quarterly* and *Exceptional Children* being selected as the top journals, together with *Learning Disability Quarterly* in the list, signify the close association between the concept of differentiated instruction and inclusivity or student diversity in contemporary educational contexts.

Conclusions

This bibliometric research on the most-cited educational papers related to differentiated instruction has revealed some interesting findings. The results indicated that, owing to the increase in publications and citations, the topic is of interest to many scholars. The analysis discovered that the highest number of publications on the topic came into existence between the years 2006 to 2013. The analysis also revealed that in terms of cited educational research, author Carol McDonald Connor has contributed to the greatest number of publications, while Florida Center for Reading, the University of Connecticut, and the College of William and Mary were found to be the top three institutions in terms of collaborating to the scholarly work on differentiated instruction. Additionally, with 69 publications the USA has made the greatest contribution to the most-cited publications on differentiated instruction as a source country. It was also discovered that the majority of the most-cited publications appeared in Q1-ranked journals, whereby the journal *'Gifted Child Quarterly'* published the most articles on the topic.

This science mapping of wide-ranging literature on the topic of differentiated instruction has revealed important findings about the most prominent authors, journals, institutions, and countries. Hence, these findings provide insights for future researchers, interested in the topic of DI, regarding the key authors, important keywords, and where to target their publications. These findings also add richness to the knowledge-base informing differentiated instruction by way of presenting an overview of the existing knowledge.

Limitations

There are some weaknesses inherent to the design of this study. When obtaining the list of the most-cited papers, the search was based on the absolute number of citations that each article has received. This could indicate a preference for older articles rather than the more recent publications, despite the quality and the influence of the latter. In addition to the duration, there might be other potential influences that have affected citation rates which we could not account for, including journal and author self-citations, as well as accessibility of the materials to other scholars. The data used in this study are derived from the Elsevier SCOPUS database. Analysis of the most-cited research, sourced from a single database, can be an additional limitation of this study. Hence, given these limitations, it is recommended that further studies should be conducted which involve expanded time scales, together with more data from other databases/sources.

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Appendix A

(The 100 most-cited articles and their details)

No.	Authors, Year	Title of Article	Journal Name	Journal Cite Score	Cited by	Normalized Citation
1	Schwartz D.L., Bransford J.D. (1998)	A time for telling	Cognition and Instruction	3.7	545	26
2	Davies R.S., Dean D.L., Ball N. (2013)	Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course	Educational Technology Research and Development	3.29	277	46
3	Valli L., Buese D. (2007)	The changing roles of teachers in an era of high-stakes accountability	American Educational Research Journal	4.14	272	23
4	Kunter M., Baumert J. (2006)	Who is the expert? Construct and criteria validity of student and teacher ratings of instruction	Learning Environments Research	2.11	136	10
5	Harrison A.G., Grayson D.J., Treagust D.F. (1999)	Investigating a Grade 11 student's evolving conceptions of heat and temperature	Journal of Research in Science Teaching	4.31	113	6
6	Vaughn S., Moody S.W., Schumm J.S. (1998)	Broken promises: Reading instruction in the resource room	Exceptional Children	3.37	91	4
7	Zydney J.M., Warner Z. (2016)	Mobile apps for science learning: Review of research	Computers and Education	7.72	86	29
8	Laukenmann et al, (2003)	An investigation of the influence of emotional factors on learning in physics instruction	International Journal of Science Education	1.89	82	5
9	Shaw S.R., McCabe P.C. (2008)	Hospital-to-school transition for children with chronic illness: Meeting the new challenges of an evolving health care system	Psychology in the Schools	1.54	78	7
10	Hooper S. (1992)	Cooperative learning and computer-based instruction	Educational Technology Research and Development	3.29	71	3
11	Mastropieri et al., (2006)	Differentiated curriculum enhancement in inclusive middle school science: Effects on classroom and high-stakes tests	Journal of Special Education	2.43	70	5
12	Menekse M., Stump G.S., Krause S., Chi M.T.H. (2013)	Differentiated overt learning activities for effective instruction in engineering classrooms	Journal of Engineering Education	5.56	68	11
13	Wertheim C., Leyser Y. (2002)	Efficacy beliefs, background variables, and differentiated instruction of Israeli prospective teachers	Journal of Educational Research	1.36	67	4
14	Ho I.T., Hau K.-T. (2004)	Australian and Chinese teacher efficacy: Similarities and differences in personal instruction, discipline, guidance efficacy and beliefs in external determinants	Teaching and Teacher Education	3.45	66	4
15	Reis et al., (2011)	The effects of differentiated instruction and enrichment pedagogy on reading achievement in five elementary schools	American Educational Research Journal	4.14	66	8
16	Subban P. (2006)	Differentiated instruction: A research basis	International Education Journal	0.49	66	5
17	Connor et al., (2011)	Testing the impact of child characteristics × instruction interactions on third graders reading comprehension by differentiating literacy instruction	Reading Research Quarterly	0.73	64	8
18	Brown T.S., Perry F.L., JR. (1991)	A Comparison of Three Learning Strategies for ESL Vocabulary Acquisition	TESOL Quarterly	3.14	63	2
19	Moody et al., (2000)	Reading instruction in the resource room: Set up for failure	Exceptional Children	3.16	58	3
20	VanTassel-Baska J.,	Toward best practice: An analysis of	Gifted Child Quarterly	3.34	57	5

	Brown E.F. (2007)	the efficacy of curriculum models in gifted education				
21	Santamaria L.J. (2009)	Culturally responsive differentiated instruction: Narrowing gaps between best pedagogical practices benefiting all learners	Teachers College Record	1.57	56	6
22	Riding R.J., Watts M. (1997)	The effect of cognitive style on the preferred format of instructional material	Educational Psychology	1.5	55	3
23	Westberg et al., (1993)	The Classroom Practices Observation Study	Journal for the Education of the Gifted	1.57	55	2
24	Tomlinson C.A. (2000)	Reconcilable differences? Standards-based teaching and differentiation	Educational Leadership	0.92	54	3
25	Baglieri S., Knopf J.H. (2004)	Normalizing difference in inclusive teaching	Journal of Learning Disabilities	0.2	53	4
26	Kang S., Scharmann L.C., Noh T., Koh H. (2005)	The influence of students' cognitive and motivational variables in respect of cognitive conflict and conceptual change	International Journal of Science Education	3.34	50	4
27	Riess W., Mischo C. (2010)	Promoting systems thinking through biology lessons	International Journal of Science Education	1.89	47	5
28	Anderson K.C., Leinhardt G. (2002)	Maps as representations: Expert novice comparison of projection understanding	Cognition and Instruction	1.89	46	3
29	Ben-David et al., (2011)	Effects of aging and noise on real-time spoken word recognition: Evidence from eye movements	Journal of Speech, Language, and Hearing Research	3.7	44	6
30	Nelson N.W., Van Meter A.M. (2007)	Measuring written language ability in narrative samples	Reading and Writing Quarterly	2.09	44	4
31	Connor et al., (2011)	Effective classroom instruction: Implications of child characteristics by reading instruction interactions on first graders' word reading achievement	Journal of Research on Educational Effectiveness	1.14	42	5
32	Donaldson et al., (2008)	Angling for access, bartering for change: How second-stage teachers' experience differentiated roles in schools	Teachers College Record	NA	42	4
33	Rosen Y., Beck-Hill D. (2012)	Intertwining digital content and a one-to-one laptop environment in teaching and learning; Lessons from the time to know program	Journal of Research on Technology in Education	2.38	39	6
34	Edens et al., (2001)	Effects of positive impression management on the Psychopathic Personality Inventory	Law and Human Behavior	2.08	38	2
35	Papadopoulos T.C. (2001)	Phonological and cognitive correlates of word-reading acquisition under two different instructional approaches in Greek	European Journal of Psychology of Education	2.67	38	2
36	White C.N., Poldrack R.A. (2014)	Decomposing bias in different types of simple decisions	Journal of Experimental Psychology: Learning Memory and Cognition	2.93	38	8
37	Yaman et al., (2010)	Parenting in an Individualistic Culture with a Collectivistic Cultural Background: The Case of Turkish Immigrant Families with Toddlers in the Netherlands	Journal of Child and Family Studies	3.32	38	4
38	Sandholtz J.H., Ogawa R.T., Scribner S.P. (2004)	Standards gaps: Unintended consequences of local standards-based reform	Teachers College Record	NA	37	2
39	Tomlinson C.A. (1995)	Deciding to Differentiate Instruction in Middle School: One School's Journey	Gifted Child Quarterly	2.03	37	2
40	Beecher M., Sweeny S.M. (2008)	Closing the Achievement Gap With Curriculum Enrichment and Differentiation: One School's Story	Journal of Advanced Academics	3.45	35	3
41	De Neve D., Devos	The importance of job resources and	Teaching and Teacher	1.63	35	9

	G., Tuytens M. (2015)	self-efficacy for beginning teachers' professional learning in differentiated instruction	Education			
42	Folstein J.R., Van Petten C. (2004)	Multidimensional rule, unidimensional rule, and similarity strategies in categorization: Event-related brain potential correlates	Journal of Experimental Psychology: Learning Memory and Cognition	2.93	35	2
43	Landrum T.J., McDuffie K.A. (2010)	Learning styles in the age of differentiated instruction	Exceptionality	1.57	35	4
44	Helwig R., Anderson L., Tindal G. (2002)	Using a concept-grounded, curriculum-based measure in mathematics to predict statewide test scores for middle school students with LD	Journal of Special Education	3.34	34	2
45	Ryan S., Ferguson D.L. (2006)	On, yet under, the radar: Students with Fetal Alcohol Syndrome Disorder	Exceptional Children	0.58	34	3
46	Gamoran A., Weinstein M. (1998)	Differentiation and opportunity in restructured schools	American Journal of Education	2.43	32	2
47	Smit R., Humpert W. (2012)	Differentiated instruction in small schools	Teaching and Teacher Education	3.45	32	5
48	Minott M.A. (2010)	Reflective teaching as self-directed professional development: Building practical or work-related knowledge	Professional Development in Education	1.75	31	3
49	Reis et al., (2004)	Reading instruction for talented readers: Case studies documenting few opportunities for continuous progress	Gifted Child Quarterly	1.97	31	2
50	Reis et al., (2007)	Using planned enrichment strategies with direct instruction to improve reading fluency, comprehension, and attitude toward reading: An evidence-based study	Elementary School Journal	2.08	31	3
51	Owens P., Sweller J. (2008)	Cognitive load theory and music instruction	Educational Psychology	1.57	30	3
52	Othman et al., (2016)	Investigating the relationship between the student's ability and learning preferences: Evidence from year 7 mathematics students	New Educational Review	1.57	29	10
53	Invernizzi M., Hayes L. (2004)	Developmental-spelling research: A systematic imperative	Reading Research Quarterly	3.14	28	2
54	Kim Y.-S., Apel K., Al Otaiba S. (2013)	The relation of linguistic awareness and vocabulary to word reading and spelling for first-grade students participating in response to intervention	Language, Speech, and Hearing Services in Schools	0.45	28	5
55	VanTassel-Baska J. (2005)	Gifted programs and services: What are the non-negotiables?	Theory into Practice	1.69	28	2
56	Durkin K., Rittle-Johnson B. (2015)	Diagnosing misconceptions: Revealing changing decimal fraction knowledge	Learning and Instruction	1.52	27	7
57	Latz et al., (2008)	Peer coaching to improve classroom differentiation: Perspectives from project CLUE	Roeper Review	4.79	27	2
58	McKenna J.W., Shin M., Ciullo S. (2015)	Evaluating Reading and Mathematics Instruction for Students with Learning Disabilities	Learning Disability Quarterly	0.6	26	7
59	Verachtert P., de Fraine B., Onghena P., Ghesquière P. (2010)	Season of birth and school success in the early years of primary education	Oxford Review of Education	2.15	26	3
60	VanTassel-Baskaet al, (2008)	A study of differentiated instructional change over 3 years	Gifted Child Quarterly	1.52	25	2
61	Dixon et al, (2014)	Differentiated instruction, professional development, and teacher efficacy	Journal for the Education of the Gifted	2.1	24	5
62	Mathes et al., (2003)	A Comparison of Teacher-Directed versus Peer-Assisted Instruction to Struggling First-Grade Readers	Elementary School Journal	1.57	24	2
63	Whitson W.L. (1995)	Differentiated service: A new reference model	The Journal of Academic	1.97	24	1

			Librarianship			
64	Berninger V.W., Richards T.L., Abbott R.D. (2015)	Differential diagnosis of dysgraphia, dyslexia, and OWL LD: behavioral and neuroimaging evidence	Reading and Writing	3.7	23	6
65	Halloun I. (1998)	Schematic concepts for schematic models of the real world: The Newtonian concept of force	Science Education	2.35	23	1
66	Jacobs et al., (1997)	Japanese and American teachers' evaluations of mathematics lessons: A new technique for exploring beliefs	Journal of Mathematical Behavior	0.92	23	1
67	Tawfik A.A., Lilly C. (2015)	Using a Flipped Classroom Approach to Support Problem-Based Learning	Technology, Knowledge and Learning	1.72	23	6
68	Bottge et al., (2009)	Assessing and tracking students' problem solving performances in anchored learning environments	Educational Technology Research and Development	1.23	22	2
69	Cassidy J., Ortlieb E., Grote-Garcia S. (2016)	Beyond the Common Core: Examining 20 Years of Literacy Priorities and Their Impact on Struggling Readers	Literacy Research and Instruction	1.04	22	7
70	Chamberlin M., Powers R. (2010)	The promise of differentiated instruction for enhancing the mathematical understandings of college students	Teaching Mathematics and its Applications	0.85	22	2
71	Jenkins et al., (2013)	Responsiveness to intervention in reading: Architecture and practices	Learning Disability Quarterly	3.29	22	4
72	Tobin R., McInnes A. (2008)	Accommodating differences: Variations in differentiated literacy instruction in Grade 2/3 classrooms	Literacy	1.52	22	2
73	Watts-Taffe et al., (2012)	Differentiated instruction: Making informed teacher decisions	Reading Teacher	0.88	22	3
74	Connor et al., (2014)	Capturing the complexity: Content, type, and amount of instruction and quality of the classroom learning environment synergistically predict third graders' vocabulary and reading comprehension outcomes	Journal of Educational Psychology	5.81	21	4
75	Nickles III G.M., Melloy B.J., Gramopadhye A.K. (2003)	A comparison of three levels of training designed to promote systematic search behavior in visual inspection	International Journal of Industrial Ergonomics	0.65	21	1
76	Kanevsky L. (2011)	Deferential differentiation: What types of differentiation do students want?	Gifted Child Quarterly	4.02	20	3
77	Morelli S., Battistini A., Catani F. (2014)	Rapid assessment of flood susceptibility in urbanized rivers using digital terrain data: Application to the Arno river case study (Firenze, northern Italy)	Applied Geography	2.11	20	4
78	Roy A., Guay F., Valois P. (2013)	Teaching to address diverse learning needs: Development and validation of a Differentiated Instruction Scale	International Journal of Inclusive Education	1.58	20	3
79	Pettig K.L. (2000)	On the road to differentiated	Educational Leadership	4.32	19	1
80	Robinson J.P. (2008)	Evidence of a differential effect of ability grouping on the reading achievement growth of language-minority Hispanics	Educational Evaluation and Policy Analysis	1.57	19	2
81	Simpkins P.M., Mastropieri M.A., Scruggs T.E. (2009)	Differentiated curriculum enhancements in inclusive fifth-grade science classes	Remedial and Special Education	2.89	19	2
82	Huang T.-C., Lin C.-Y. (2017)	From 3D modeling to 3D printing: Development of a differentiated spatial ability teaching model	Telematics and Informatics	4.94	18	9
83	Robinson et al., (2014)	The Effects of a Science-Focused STEM Intervention on Gifted Elementary Students' Science Knowledge and Skills	Journal of Advanced Academics	0.2	18	4
84	Huebner T.A. (2010)	Differentiated instruction	Educational Leadership	1.2	17	2
85	Zhan S. (2008)	Changes to a Chinese pre-service	Asia-Pacific Journal of	0.58	17	2

		language teacher education program: Analysis, results and implications	Teacher Education			
86	Aguilar M. (2017)	Engineering lecturers' views on CLIL and EMI	International Journal of Bilingual Education and Bilingualism	3.34	16	8
87	Bianco M., Carothers D.E., Smiley L.R. (2009)	Gifted students with Asperger's syndrome: Strategies for strength-based programming	Intervention in School and Clinic	2	16	2
88	Dingle et al., (2011)	Developing effective special education reading teachers: The influence of professional development, context, and individual qualities	Learning Disability Quarterly	1.57	16	2
89	Goddard et al., (2010)	A multilevel exploratory study of the relationship between teachers' perceptions of principals' instructional support and group norms for instruction in elementary schools	Elementary School Journal	0.2	16	2
90	Jones R.E., Yssel N., Grant C. (2012)	Reading instruction in tier 1: Bridging the gaps by nesting evidence-based interventions within differentiated instruction	Psychology in the Schools	1.54	16	2
91	McGill-Franzen A., Allington R.L. (1990)	Comprehension and coherence: Neglected elements of literacy instruction in remedial and resource room services	Journal of Reading, Writing, and Learning Disabilities International	1.97	16	1
92	Nielsen K.H. (2013)	Scientific Communication and the Nature of Science	Science and Education	1.52	16	3
93	Njin et al, (2008)	Beginning special education teachers classroom reading instruction: Practices that engage elementary students with learning disabilities	Exceptional Children	3.34	16	1
94	Gierl M.J., Lai H. (2013)	Evaluating the quality of medical multiple-choice items created with automated processes	Medical Education	2.08	15	3
95	Goodnough K. (2010)	Investigating pre-service science teachers' developing professional knowledge through the lens of differentiated instruction	Research in Science Education	1.87	15	2
96	Hewson M.G., Hewson P.W. (2003)	Effect of instruction using students' prior knowledge and conceptual change strategies on science learning	Journal of Research in Science Teaching	3.34	15	1
97	Milman et al., (2014)	Examining Differentiation and Utilization of iPads Across Content Areas in an Independent, PreK-4th Grade Elementary School	Computers in the Schools	3.7	15	3
98	Niemi et al., (2011)	Task avoidance, number skills and parental learning difficulties as predictors of poor response to instruction	Journal of Learning Disabilities	3.58	15	2
99	Park V., Datnow A. (2017)	Ability grouping and differentiated instruction in an era of data-driven decision making	American Journal of Education	4.04	15	8
100	Santangelo T., Tomlinson C.A. (2012)	Teacher Educators' Perceptions and Use of Differentiated Instruction Practices: An Exploratory Investigation	Action in Teacher Education	0.61	15	2

NA=Data not available from SCOPUS Website.